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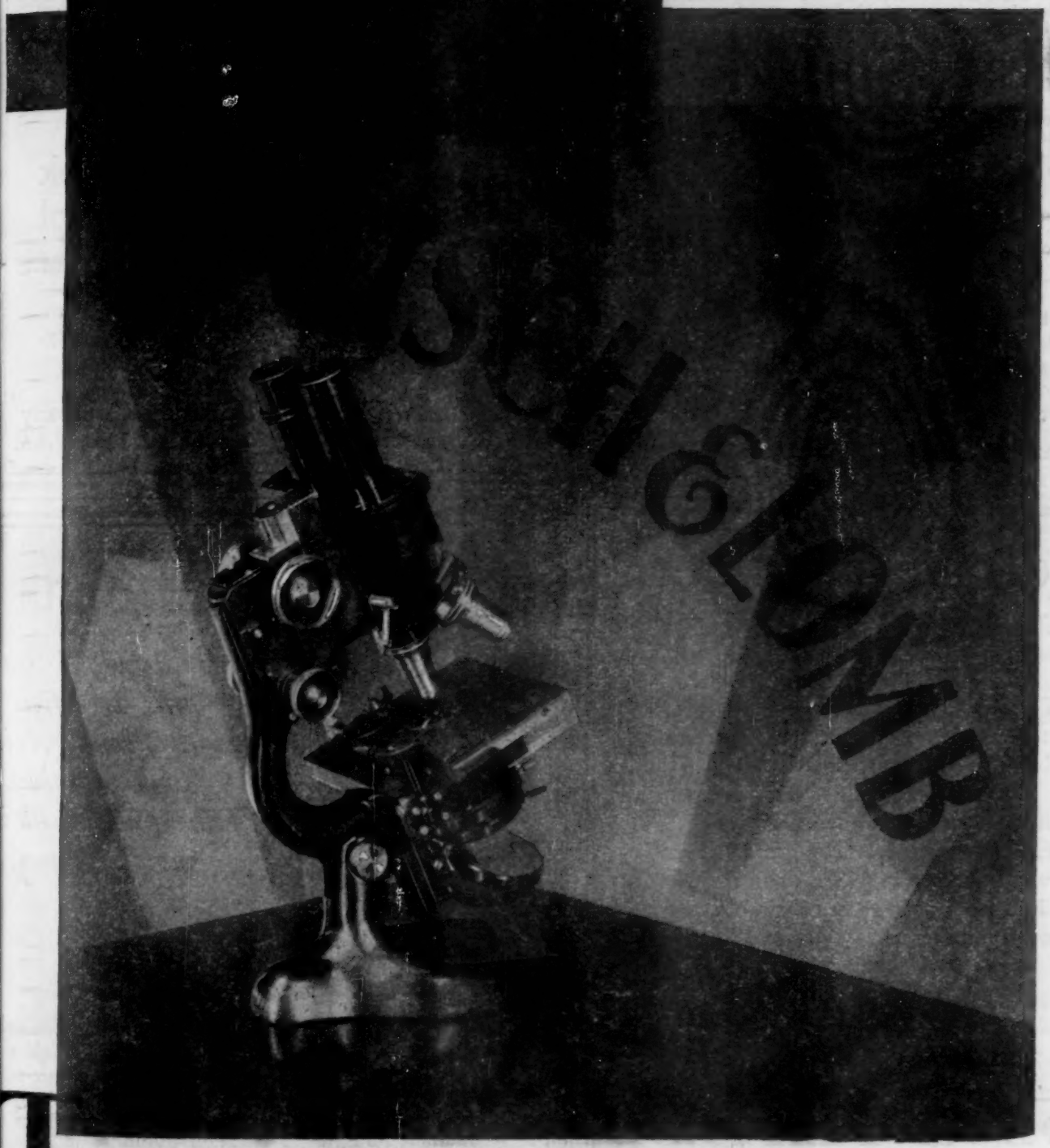

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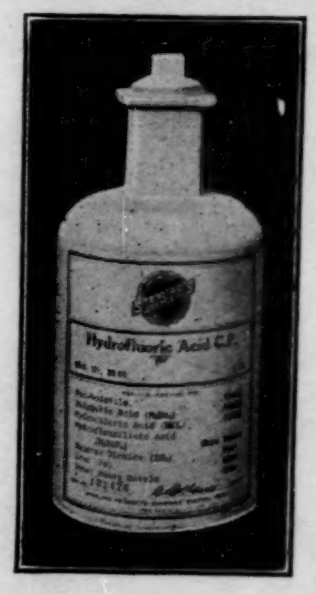

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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

THE SCIENTIFIC RETROSPECT[1]

IN selecting a title for this address at rather short notice, I took the precaution to provide the bow I was drawing (somewhat at a venture) with more than one string. I propose to avail myself of two such strings: first a few remarks on scientific history and secondly a glance at the remarkable way in which our available scientific retrospect has recently been expanding.

We scientific workers are perhaps too neglectful of our past history for the obvious reason that our present is so engrossing. It is a necessity of the game to concentrate attention on the present, and even deliberately to clear the past from our minds; just as in playing cards we must remember the particular hand we are playing and forget those which preceded it. But even in playing cards certain exceptional hands, illustrating a novel situation or calling attention to possible new developments, live in the memory, are described by writers on "bridge," and eagerly read by their readers; and similarly in scientific work there are incidents and epochs which we should do well to recall, and even to keep before our minds, as stimuli to our work or guides in conducting it. May I give a few instances, chiefly from my own department of astronomy?

The name of Kepler is widely and justly known in connection with his three great laws, but he may also be remembered as a man who faced heroically as great a disappointment as a scientific worker can well meet. He thought he had discovered the secret of the structure of the universe and his hopes were completely dashed. His universe was practically limited to the solar system, as Copernicus had explained it, of six planets circulating round the sun each on the surface of its own sphere. The six spheres were a legacy from older conceptions, which Kepler himself was presently to destroy, but in the five spaces intervening between these six spheres, as Copernicus had pictured them, Kepler found that he could fit the five regular solids. Some of you may hear for the first time that there are five regular solids and no more; the number of regular plane figures (triangles, squares, penta-

[1] An address to "scientific workers" delivered during the New York meeting of the American Association for the Advancement of Science, on the afternoon of Friday, December 28, 1928.

gons, and so on) is so obviously unlimited that the reason for limiting the solids does not readily occur to the uninitiated. To these I may perhaps explain how the limitation comes from the nature of a corner in a regular solid. Let us think for a moment of a cube, which is the most familiar of the five. To each corner there are three faces meeting in the point, and it is obvious that there must always be at least three such faces. We can not make a corner with two. Moreover, in the particular case when the faces are squares, we can not have more than three; if we try to make four squares meet together, they obstinately form a plane and the corner disappears. If we use pentagons instead of squares, we can again make three pentagons meet in a corner but four will behave like an umbrella blown inside out by the wind; we could not build up a closed solid with corners of that kind. And if we try to use hexagons for the faces, even three of them fit into a plane as did the four squares; they make the familiar honeycomb pattern. Hence we have so far got only two regular solids, made with squares and pentagons, and it is pretty clear that to go beyond hexagons is useless. We turn back to equilateral triangles, and here our luck improves. We can make a corner with three triangles or four or even five, but when we try to use six we get the same flat result as with four squares or three hexagons. Hence there can be no more than five regular solids, three formed with triangles, one with squares and one with pentagons. And Kepler's great discovery was that these five would fit in admirably between the six planetary spheres, so that if the corners of one solid were on the outer sphere its faces would touch the inner. Thus he placed a cube with all its corners on the sphere of Saturn; inside the cube he put a sphere touching the faces of the cube, and lo! that was the sphere of Jupiter. The other solids each occurred once and once only as in the following table, and if we allow our minds to unhook themselves for a moment from the prejudices of modern knowledge we must admit that here was marvelous evidence of a great design. Just six planets (nearly two centuries were to elapse before the number was increased) and just five solids and no more: one solid for each interval without repetition or omission. Surely the Plan of the World was detected? There was just one doubt: the figures given by Copernicus (without suspicion of the use Kepler was to make of them) did not precisely fit the geometry of the edifice. The following table shows (in the column headed "Kepler") what exact geometry required, and it will be seen that the figures differ somewhat from those in the column "Copernicus." Even then we must admire the closeness of the fit, which has no glaring exception. Small wonder that Kepler confidently believed the differences to be due to the imperfect estimates of Copernicus. He felt sure that if he could get more accurate measures of the planetary distances the errors would disappear and the perfection of the whole be made

KEPLER'S GREAT SCHEME

	Kepler	Copernicus
Saturn	1060	1000
Cube		
Jupiter	612	635
Tetrahedron		
Mars	204	212
Dodecahedron		
The Earth	162	160
Icosahedron		
Venus	128	127
Octahedron		
Mercury	91	92

manifest, and he felt sure also that he could get better measures from the great Tycho Brahe. By that time Tycho had had to leave his native land and had been welcomed at Prague, so to Prague Kepler went in high hopes. And then his house of cards tumbled to bits. Tycho would have none of it, or of the kind of intuitive principles which it represented; he inculcated the severer methods of patience and toil in observing. Have we the imagination to sympathize fully with the terrible disappointment? Have we the heroism to follow Kepler, however distantly, from the abasement to which he had been cast down in his rise to the even greater discovery of the mechanism rather than the design of the solar system?

The International Union of Geodesy and Geophysics was most hospitably entertained at Prague in 1927. Several astronomers attended the meeting and accompanied the Astronomer Royal of England when he laid a wreath on the tomb of Tycho Brahe. From an observatory tower we saw also the curiously roofed house in which Kepler lived and in which he must have worked out from his master's observations the three great laws known by his name. I throw on the screen one or two slides of these surroundings, which I owe to the kindness of Professor Nušl and Dr. Frič.

Let us now turn to an incident nearly contemporary with Kepler's disillusionment, the great demonstration experiment of Galileo when he dropped two unequal weights from the top of Pisa's leaning tower, and showed that they fell together—not, as Aristotle had said, with speeds in the ratio of their weights. The authority of Aristotle had sufficed to maintain this erroneous belief for a couple of thousand years, and in recoil from the error there is some temptation to

underestimate Aristotle. But this temptation is to be resisted for many good reasons, and I take the opportunity to mention a comparatively new one, showing the important relationship of this great man to Greek astronomy (as we usually think of it). My friend, Dr. J. K. Fotheringham, recently delivered a lecture of thrilling interest on "The Indebtedness of Greek to Chaldaean Astronomy,"[2] in which he shows how the Chaldaean astronomers, especially Naburianos and Cidenas, had built up a wonderful series of observations of eclipses for about 360 years and discussed them so as to obtain the constants of the lunar theory with an accuracy quite marvelous for that era. To quote one or two sentences from the lecture:

(a) It is the rarest thing for a modern observatory to continue a program of observations through thirty years, let alone 360. The only modern observations that can compare in continuity with the Babylonian are the Greenwich meridian observations which have been maintained since 1750. Against these I have nothing to say, but their analysis is not so simple as it once seemed, and we could do with another Cidenas.

(b) So it seems that Cidenas's "Canon of Eclipses" actually contained a better value for [the motion of the Sun from the Moon's Node] than that which is used in our standard modern canon [Oppolzer's].

Now this wonderful reservoir of astronomical information became accessible to the Greeks through Aristotle's initiative: without it we might never have heard of Hipparchus and Ptolemy. To quote two more sentences from the lecture:

(c) The great event in the development of exact astronomy in Greece was the sending of a collection of Babylonian observations by Callisthenes at the request of his uncle, Aristotle.

(d) If the aim of astronomy is to give an accurate numerical representation of phenomena on which predictions may be based, then Naburianos, Cidenas, Hipparchus, Ptolemy stand by themselves and each builds on the work of his predecessors. There were no others of the same caliber till Tycho Brahe and Kepler.

If ever then we are tempted to picture Aristotle as neglecting observations we have an antidote in remembering this action of his which secured to the Greeks the advantages of observations which they did not themselves make. We may rest assured that Aristotle would not have approved the use made of his great name to uphold authority and prejudice against observation.

Nor does the conflict belong to those early days alone: we have seen it just as bitter in the nineteenth century over the doctrine of evolution. As I am here representing the British Association perhaps I may venture to recall the historic scene at the Oxford meeting in 1860, when Bishop Wilberforce undertook to destroy the new and pernicious hypothesis outlined by Charles Darwin, a scene which may not be so well known on this side of the Atlantic as on the other. It will at least serve the purpose of showing, when we are dealing with the historical aspects of science, how difficult it is to obtain an accurate record of facts, even when many witnesses are available. Up to a certain point the witnesses are all agreed. The battle between Wilberforce and Huxley, Hooker and others arose rather unexpectedly. The announcement that the eloquent bishop would speak on the thorny subject attracted a greater crowd than had been foreseen, so that the meeting was changed to a larger room. Wilberforce made an undoubtedly persuasive speech, following the lines of a review which had appeared shortly before and was obviously from his pen; but he made an important error of tactics (and perhaps of good manners) at one point of it. Turning to Huxley he inquired suavely whether it was on his grandfather's or his grandmother's side that he was descended from an ape. So far all accounts are in substantial accord: but they differ considerably as to the exact nature of Huxley's reply. I will quote two of them: the first written by the historian John Richard Green, then an undergraduate, in a letter to a friend;[3] the second by the biographer of Bishop Wilberforce. Green's letter gives the following version:

I asserted, and I repeat, that a man has no reason to be ashamed of having an ape for a grandfather. If there were an ancestor whom I should feel shame in recalling, it would be a *man*, a man of restless and versatile intellect, who, not content with an equivocal success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance, only to obscure them by an aimless rhetoric, and distract the attention of his hearers from the real point at issue by eloquent digressions, and skilled appeals to religious prejudice. ["Life and Letters of Charles Darwin," II, p. 322. The word "equivocal" was challenged as incorrect.]

The second version is from the "Life of Bishop Wilberforce," written by his son, and gives Huxley's reply as being "that he would sooner have been descended from an ape than a bishop." It is tolerably easy to understand the difference between the two versions: but it might have been harder to infer the truth if we had had only one of them.

[2] See *The Observatory* magazine for October last.

[3] The friend, Professor Boyd-Dawkins, died on January 15, 1929, in his ninety-second year, soon after these words were spoken.

I will add another illustration of the difficulties of getting exact history. It is impossible to think of Galileo and Tycho and Kepler without thinking of Newton, and though to give rein to our thoughts would take us too far, we may find in the very greatness of his name and fame reason for surprise that some of the stories about him should be so ill founded. Doubtless most of us have heard or read of the burning of some of his papers by the agency of his little dog, and of the gentleness of his reproof "Oh! Diamond, Diamond, thou little knowest the mischief done!" Again we know the story of the hole under the door for his cat to enter or leave the room, and the additional smaller hole made for the convenience of the kittens when they came into the world. But it seems quite certain that these stories are baseless, for we have the statement of Dr. Humphrey Newton, who lived with him for the important five years, 1684–1688, that he heartily disliked both dogs and cats, and would never have either near him!

I turn now to the other string of my bow: the recent great expansion of the period of time over which we consider ourselves justified in looking backward. At the epoch to which I have just been referring, when Darwin put forward his theory of natural selection for which a long period of slow development was required, Sir William Thomson (Lord Kelvin) was only prepared to allow one hundred million years for the past age of the earth; his colleague, Professor P. G. Tait, went further in restriction and would only allow ten million. In 1869 Charles Darwin wrote:

> Thomson's views of the recent age of the world have been for some time one of my sorest troubles.

and again in 1871:

> I can say nothing more about missing links than what I have said. I should rely much on pre-Silurian times: but then comes Sir W. Thomson like an odious spectre.

There was in fact a sharp difference of opinion between biologists and geologists, who demanded a long past age, and physicists, who insisted on a short one—a difference which persisted almost to the end of the nineteenth century. Special attention was recalled to it by Lord Salisbury's presidential address to the British Association at its Oxford meeting of 1894, a third of a century later than the dramatic scene of 1860. Accordingly, in 1896, Professor Poulton devoted his presidential address to Section D (Zoology) to a consideration of the arguments of the physicists, in order to see how far the claims of the paleontologists could be satisfied. (May I acknowledge in passing my great indebtedness to this address for our present purpose?) He reviewed three lines of argument which had been used, and in all three great changes have been made in the thirty years which have since elapsed, though in the previous thirty, as we have seen, the situation had been scarcely modified at all. He considered the Moon's movements, the Earth's cooling and the Sun's past life, as regards all of which we have learnt much in the present century.

New tables of the Moon's detailed movements have been prepared in this country by E. W. Brown, building on the foundations laid by G. W. Hill. They represent a very fine piece of successful work, but they do not directly concern the problem reviewed by Professor Poulton, which considers the relations of the Earth and Moon introduced by the tides. The Moon holds up the tides against the Earth's rotation, causing a certain amount of friction which slowly retards that rotation. This again reacts on the Moon to drive it further away from the Earth: hence its present distance of 240,000 miles was less in the past, and looking backwards we can trace it to be less and less until the Moon was very near the Earth, and looking back further still we come to a time when the Moon was probably just detached from the Earth, of which it previously formed part. All this was realized long ago, and Sir G. H. Darwin had mathematically traced the Earth-Moon's history backwards in this way to a time when the two bodies were both rotating in about six hours as a twin body. His result for the length of the history from that time to the present was something over fifty-seven million years. But there were two uncertainties affecting this calculation: the first as to the amount of the frictional effect at the present time, which rendered the starting point for the backward glance rather vague, the second as to the precise character of the friction. It was apparently difficult to trace an adequate friction in the tides of the deep oceans, which rolled too smoothly. An alternative suggestion of finding a sufficient effect in the elastic deformation of the solid earth succeeded no better. It was only in the present century (and in fact during the great war) that G. I. Taylor was led to study the behavior of shallow seas, and to find an adequate response. The shallow seas differ from the deep oceans in somewhat the same way as a brawling stream from a placid river: they have a character which he called "turbulence," of which he found sufficient in the Irish Sea (do we recognize here a certain appropriateness?) to cause a sensible part of the estimated frictional delay of the Earth's rotation. H. Jeffreys carried on the good work to other seas, and J. K. Fotheringham showed that the correspondence of the total to his estimate from eclipses was satisfactorily exact.

Eclipses of the Sun and Moon provide the means of estimating the amount of this slow change in the Earth's rotation and the Moon's orbit. It requires no telescope to recognize that on one occasion the Moon is totally eclipsed, or that on another half the Sun is covered up a few hours after midday: so that we get exact observations of the relative positions of the Sun and the Moon in ages past. At least it was hoped that they were exact up to nearly the end of the last century: but it had gradually become clear that there was something wrong in either the historical records or the extension of our modern astronomical tables back to past times. Few people were competent to criticize both elements of the problem, so that the astronomers were inclined to blame the historians as inaccurate and the historians doubted the capability of the astronomers to project themselves back into the past: in either case the problem had almost been put aside as insoluble. Interest in it was revived by P. H. Cowell, and promptly followed up by J. K. Fotheringham, who was almost the first scholar to combine remarkable historical knowledge with astronomical. (The value of his work has been recognized by his appointment as reader in ancient astronomy and chronology in the University of Oxford.) He deduced values for the elements of the slow changes in the movements of the Moon and Earth which satisfactorily fitted the ancient records when certain changes were allowed in the historical interpretation of them. Let me give one illustration from the most famous eclipse of antiquity—that predicted by Thales of Miletus and recorded by Herodotus:

> There was war between the Lydians and the Medes for five years: each won many victories over the other, and once they fought a battle by night. They were still warring with equal success, when it chanced, at an encounter which happened in the sixth year, that during the battle the day was turned to night. Thales of Miletus had foretold this loss of daylight to the Ionians, fixing it within the year in which the change did indeed happen. So when the Lydians and Medes saw the day turned to night they ceased from fighting, and both were the more zealous to make peace. Those who reconciled them were Syennesis the Cilician and Labynetus (=Nebuchadnezzar) the Babylonian. [Translation of Herodotus by A. D. Godley.]

The eclipse was that of May 28, 585 B. C., but "astronomers, misled by historical students, have generally assumed that the fighting would be near the river Halys (in the north of Asia Minor) . . . and have attempted to amend the lunar theory accordingly." Dr. Fotheringham's new information shifts the track to the south, where not only is the battlefield near Cilicia (over which Syennesis was ruler) but it includes the Pisidian road, the importance of which for military purposes was quite independently pointed out by Sir William Mitchell Ramsay.[4] It will be seen that in this instance both history and astronomy required adjustment. Dr. Fotheringham has had the further satisfaction of finding confirmation of his suggested figures in the tablets for the rising and setting of Venus,[5] and in others relating to commercial contracts. The general outcome is that we now have a good accordance between astronomy and history, with a satisfactory chronology back to the time of Abraham. So far as this it is not *very* different from that of our old friend, Archbishop Ussher, though we do not thus learn anything of times before Abraham wherein lay the differences, not merely between the biblical chronology and the geological, but between the geological and the physical.

As concerning our earth itself, the main line of physical argument was from its rate of cooling, on the assumption that it had no way of renewing its heat, but was just a body that had once been hot. The cooling of our earth or of a plate of porridge is most obvious near the boundary: as we dig down into the earth we find it warmer: and from the rate at which it grows warmer Lord Kelvin estimated how long it had been cooling. Even then he had to make certain assumptions as to its conductivity: and after Lord Salisbury's address in 1894, John Perry pointed out that a change in these assumptions might make a good deal of difference. If, for instance, a conductivity ten times as great were assumed, the age of the earth would be multiplied, not by ten but by fifty-six. Of course there was no way of deciding between such assumptions because we then knew very little about the inside of the earth. And the discovery of radioactivity vitiated the whole argument, which, as above stated, assumed that the earth had no way of renewing its heat. We now know that it has such ways, and though we do not know exactly what its stores of radioactivity are, they would probably suffice to extend its past life to five thousand million years, an estimate well supported by other considerations. Let us, however, remark that we have meantime learnt some facts about the previously unknown interior of the earth from the new science of seismology. Up to near the end of the nineteenth century our knowledge of earthquakes was practically limited to the destruction near the spot where

[4] See the Halley Lecture for 1921: Oxford University Press.

[5] See "The Venus Tablets of *Ammizaduga:* a solution of Babylonian chronology by means of the Venus observations of the First Dynasty," by S. Langdon, J. K. Fotheringham and C. Schoch. Oxford University Press, 1928.

they occurred: we now have sensitive instruments which receive and record messages sent to all parts of the earth through its body, which incidentally tell us about the nature of the interior through which they travel. The transmitted waves are of various kinds, but we may here consider two of them usually denoted P and S. The letters stand for Primus and Secundus, indicating that P arrives before S; we may also remember them as exPress train and Slow train; or again we may use the letters to mean Push and Shake, for the P waves are longitudinal while the S are transverse. Consequently the P waves will traverse a fluid, as sound waves do: but the S waves will not. When therefore we find P waves arriving without accompanying S waves, we may fairly infer that fluid has intervened somewhere in the path: and this in itself suggested that some part of the earth's interior was liquid. But this suggestion was crystallized into much more definite shape by Gutenberg, who identified certain waves as S waves received before their expected time, explaining that they had traveled as P waves through the earth's liquid core. He postulated a molten iron core to the earth, of radius rather more than half that of the surface. When S waves emitted by an earthquake reach the boundary of this molten core, they can not travel further as S waves, but (by the well-known properties of a surface of discontinuity) they can generate P waves. The Slow-train passengers must go on by exPress. On arrival at the other boundary they can either continue as P waves or change back into their Slow train for the rest of the journey to the surface, where a seismograph receives them; but since they have traveled part of the way by exPress, they arrive before their expected time. Thus from the study of earthquakes which occur near the earth's surface we have learnt this important fact about its interior.

But how much more have we learnt about the Sun, by means of the radiation from its surface! The new theory of relativity has revolutionized completely our views of the origin of this radiation. The old view was that the mass of the Sun remained unaltered, but that by its slow contraction under gravity heat was generated and radiated out to us. The possibilities of radiation were thus limited by the possibilities of contraction from indefinite diffusion to possible compactness. Einstein has changed all that. Without specifying how the transformation was effected he showed from his beautiful mathematical theory that radiation came from the very body of the Sun himself; that by radiating he is shedding four million tons of himself every second, or one hundred and twenty million million tons every year, since there are thirty million seconds in a year. And yet the recognition of this spendthrift rate, far from reducing the Sun's expectation of life, has enormously increased it; for his available capital, in the shape of his own body, is immensely greater than that formerly represented by the mere shrinking of his body into compact order. Think merely how often we must mention a million in estimating the Sun's body or mass. He is a million miles high, a million miles wide, and a million miles through: to assess the cubic miles in his content we must therefore multiply together *three* millions. And then a cubic mile represents millions of tons. Think of a cartload of coal—measuring a few feet each way: in a cubic mile we could put some thousand million such carts: that makes at least *four* factors of a million for the Sun's mass in tons. If to get his life in years, we divide by his annual expenditure we drop two of the factor millions; but there are still two left: millions of millions of years instead of the hundreds of millions which were all that the physicists would allow on the old theory. The estimate works both ways, back and forward: we need have no anxiety about our immediate future, but also it becomes clearer and clearer that in the past "the geologists can have all the time they want," to use a phrase in which the closing of the controversy, at one time rather bitter, was marked by an eminent physicist.

Looking backward our vista is, however, limited by the consideration to which Professor Eddington has recently called attention in his last new book, "The Nature of the Physical World," which I will heartily commend to you as well worthy of attention. He uses the symbol of "Time's arrow" to remind us that past time can not be like future time. The universe is running down: and he compares the method of its running to the changes made in a pack of cards by shuffling. The cards come from the maker beautifully organized, reds and blacks alternately: so that to play any reasonable game with them we must shuffle them, until the organization disappears. Would it ever reappear if we go on shuffling? The answer which tempts us is, "Yes, if you go on long enough," to which Professor Eddington replies by substituting another question. By playing at random with a typewriter a monkey *might* print an intelligible sentence: how long should we expect it to be before an army of monkeys playing on all the typewriters required would print off all the books in the British Museum? By such analogies does he try to bring home to us the certainty that the universe is departing more and more from organization as time goes forward. But this also necessitates organization increasing as we go backward: and though there is no difficulty in looking forward, we recognize at once the bewilderment of looking back. Shall we not come to a time when the organization is so complete that

we can not imagine it improved? The question is a suitable conclusion to our Scientific Retrospect.

H. H. TURNER,
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RESEARCH STANDARDS IN ANIMAL HUSBANDRY[1]

THE applications of science to the problems of agriculture are of relatively recent date, both in America and in Europe. Although sporadic attempts at agricultural research had been made in earlier times, it was not until the middle of the last century that formally organized agencies were created in which the methods of science could be brought to bear upon the problems of this, the oldest field of human endeavor.

In 1843 an English gentleman organized at Harpenden, England, the first agricultural experiment station to be created in any nation. Sir John Lawes at that time, largely through his own private means, gathered together the essential features of a modest chemical laboratory and set to work upon a study of the soil as a medium of plant growth. Under the leadership of Lawes, followed subsequently by Gilbert, Hall and Russell, this station has attained an outstanding position of leadership in the field of soil science and has made noteworthy contributions to our understanding of the complex reactions of the soil.

A few years later, in 1853, a group of Saxony farmers organized an experiment station in the little German village of Möckern near Leipzig and called a young German chemist, Emil Wolff, as director of its work. Wolff's efforts were largely devoted to a study of the problems of animal husbandry with particular reference to the food requirements of farm animals. This institution, still in existence and still doing important work, may be regarded as the first animal husbandry experiment station of the world.

From these modest beginnings, one in the field of animal industry, the other in that of plant industry, the movement for the establishment of institutions for the scientific study of agricultural problems has spread into all civilized nations of the world. In the more advanced countries of western Europe and America such institutions have become both numerous and extensive, and great progress has been made.

Under the stimulus of the Federal Land Grant act and subsequent acts of Congress, the United States suddenly called into being, soon after the movement was started in Europe, a nation-wide system of agricultural colleges and experiment stations, when there were few precedents for guidance, no qualified teachers and no organized body of knowledge with which to make a fair beginning. The inevitable result was much mediocre introductory work from which escape has only recently been marked. In Europe the development has been somewhat longer in process, more gradual in growth and, particularly in the older scientific centers, more firmly grounded in the basic sciences. Such development has been the result of various factors. In the older countries of Europe many problems of agricultural practice have been solved through the cumulative experiences of farmers themselves, extending over a period of many centuries. Trial and error methods have indicated the wisdom of certain procedures and the folly of others. Furthermore, the vocational aspects of agricultural education and much of the more empirical type of investigation, such as variety tests, animal-feeding trials, fertilizer trials, plant and animal breeding, control work and other investigations of a less exacting character have been left to agricultural schools of the lower grades and independent experiment stations designed and established for this particular type of work. The agricultural colleges and research institutes of the higher types have thus been free to direct their efforts to more definitely scientific studies. In America, agricultural experiment stations have generally been established and conducted as integral parts of agricultural colleges. They have been regarded as agencies both for studies of an immediately utilitarian character and for fundamental researches requiring scientific ability of the first order. These two purposes have not always harmonized. Under the pressure for immediate results the less scientific work has too often prevailed.

While private initiative and private means established and fostered the first stages of agricultural education and research on both continents, the new movement early came to be recognized as a legitimate function of government and ever since has depended largely upon public grants for its support. This procedure finds its justification as well as its necessity in the fact that it is a primary responsibility of government to do what it can to insure an adequate supply of food and clothing for the growing needs of expanding populations. What is commonly called "aid to farmers," indeed, what is even called "farm relief" (a term to which I must confess some aversion) is primarily protection for urban populations, inasmuch as the farmer unaided can supply from the land most of the minimum necessities for human existence. Such aid to agriculture is at the same time

[1] An address delivered at the dedication of the Animal Science Building, of the University of California, College of Agriculture, at University Farm, Davis, California, November 12, 1928.

a contribution of great importance to the development of commerce and manufacture, by which millions gain their livelihood, in that it helps to guarantee a constant supply of raw materials on which commerce in part, and certain manufacturing industries wholly, depend for their existence. It is not difficult to demonstrate that aid to agriculture is a collective contribution toward the development and maintenance of one of the primary sources of national wealth and employment in the direct and indirect benefits of which all participate. This conception has entered into public policy in all civilized countries. Upon its continuance depends the welfare not alone of rural people but that of urban populations as well. So one finds the educational and research agencies of agriculture throughout the world being fostered by public opinion and drawing their major support and incentive from governmental sources.

But herein lies a weakness. Governments, fostered and stimulated by public opinion, have generally been more interested in immediate aid to production and distribution, or in meeting some pressing emergency, than in the fundamental requirements of a permanent agriculture, or the development of those phases of agricultural science, particularly the more theoretical aspects, which become finally the preconditions of further advance. Hitherto there has been much justification for emphasis on efforts promising results of immediate utility; farmers have needed help and the less difficult scientific problems have come properly into the foreground. Nor have we wholly passed this stage yet. There are still many pressing problems demanding immediate solution, if possible, particularly in the newer regions of the world where agriculture has not yet reached a stable condition. There is still some pioneering to be done.

But this period of pioneering in the more advanced countries of the world is passing. Much of the less exacting work which always accompanies the opening up of a new field of human thought has largely been done. Progress in the future lies in another direction. The demand now is for work of a more fundamental character and for teachers and investigators possessing scientific preparation of the first rank. Since the requirements of an advancing agricultural research run ahead of public opinion, policy and grant, there is a very real need and a very great opportunity for private benevolence to enter, and, through the training of men, the development of facilities and the support of research, to foster the higher and more remote, but now already imperative, fundamental and theoretical aspects of agricultural science. This involves the laying of a firmer scientific basis in agricultural research and the bringing to bear upon agricultural problems the modes of attack, methods and techniques of the physical and biological sciences basic thereto. It also involves the more rapid expansion of the underlying sciences into those newer areas of discovery which a fuller knowledge of plant and animal biology requires.

Fortunately both in Europe and America private funds are beginning to enter the field of agricultural research. Cambridge University, not only the leading center for agricultural research in Great Britain and the British Empire, but also one of the world's most outstanding centers for general science, has recently embarked upon a program of development of the physical and biological sciences in relation to agriculture that represents a new point of view and a new method of procedure in the advancement of agricultural knowledge. The Cambridge program involves, not the further development of horticulture, agronomy or animal husbandry as such, but the strengthening of facilities and staff of that university in such fields as general physiology, plant and animal physiology, plant and animal pathology, plant and animal genetics, nutrition, entomology, experimental zoology, biochemistry, biophysics and the like. This program involves an estimated cost of approximately six million dollars.

In our own country similar development is taking place. One of our great eastern universities is likewise engaged upon a similar program of development of the physical and biological sciences in relation to agriculture to the end that these sciences may be made to serve more effectively the ever-growing needs of agriculture and their methods and techniques brought to bear upon the problems of the agricultural industries. It is estimated that this scheme will cost at least nine million dollars.

Within the past five years, at least three other private benefactions to agricultural education and research in the United States, involving over a million dollars each, have been announced, and smaller amounts for specific projects have been appropriated from time to time by different educational foundations to aid agricultural colleges in their work.

Coming nearer home we have the example of the splendid opportunity that has recently come to our own university through the generosity and far-sighted wisdom of Mr. Giannini to establish a firmer basis for our studies of the economic problems of California agriculture.

These new developments and others of a similar nature which are now taking place in some of the more important agricultural centers of the world mark the dawning of a new era in agricultural research. This era could only have come after the splendid work of our predecessors who opened up this great field of human knowledge. We honor them to-

day as we set our faces toward the new goal. They have pointed the way by their explorations, superficial though many of them may have been. They have been mining the surface layer—we must extend our operations deeper.

And in this we shall find no more fruitful field for more thoroughgoing scientific exploration than that of animal husbandry, which Emil Wolff and his colleagues began three quarters of a century ago. But animal husbandry is not a science in itself; it has no effective technique of its own. Rather is it a field of human endeavor dependent for its advancement upon the sciences of physics, chemistry and biology, together with the newer outreaches, specialized branches and interrelations of these basic fields, such as genetics, nutrition, physiology, bacteriology, pathology, biochemistry and the like. These are the essential experimental sciences with which the future animal husbandry worker must be familiar and in whose disciplines, methods and techniques he must be trained. In short, these are the tools with which the future problems of animal husbandry are to be solved.

To the advancement of these sciences in their relation to animal life, to the utilization of their methods and techniques in the study of the practical problems of animal husbandry, in a word, to the highest scientific training of men and the advancement of truth, this building is reverently dedicated.

C. B. HUTCHISON

UNIVERSITY OF CALIFORNIA

ALFRED MAURICE WAKEMAN

THE death of A. Maurice Wakeman on March 2 adds another to the list of those who have given their lives unselfishly in the cause of science.

A. Maurice Wakeman was born in New York City on March 30, 1897, the son of Alfred John Wakeman and Harriett Pierson (Taylor) Wakeman. He received a B.A. degree from Yale University in 1919, graduating with honors; his M.D. degree, *cum laude*, from the same university in 1923. On June 28, 1926, he was married to Genevieve Rachel Bartlett, daughter of Dr. and Mrs. C. J. Bartlett, of New Haven.

From February 1, 1924, to October 1, 1925, he was intern at the Presbyterian Hospital in New York City; and from November, 1925, until July, 1926, was medical resident at the New Haven Hospital, New Haven, Connecticut.

At the termination of his duties as resident he accepted the position of instructor in the department of internal medicine, attached to the division of chemistry and metabolism, a position which he held until his death. In the succeeding year he was chosen by the International Health Board of the Rockefeller Foundation to spend eighteen months in the investigation of the chemical and metabolic aspects of yellow fever in Nigeria, and received leave of absence from Yale to undertake the work.

He sailed in February, 1928, for the African coast. The result of his studies in Nigeria can not yet be told in detail. When he reached Lagos the epidemic among the natives had already ceased. Fortunately, an adequate supply of monkeys, which had been proved susceptible to the disease by the work of the martyr, Stokes, afforded material for investigation. What is as yet known of his work, gathered from correspondence and brief preliminary report, reveals important contributions to the pathogenesis of the symptoms of yellow fever and, what is more important, to our knowledge of the function of the liver and the effects of its destruction by disease. He also found time to make the first study of the chemical and metabolic disturbances in a case of blackwater fever.

The story of his illness is still only partly known. In January, 1929, he was forced to bed by a stubborn phlebitis, which relapsed when he resumed activity. By the end of the month as the condition continued and his chief work was completed—he had contemplated leaving Lagos in the summer—a return to this country seemed advisable. On March 1 he was reported seriously ill, with cerebral complications, and two days later word was received that he had died at sea on the night of March 2.

A high sense of responsibility and service, without austerity; a warm sympathy and a keen humor won the respect and affection of all his associates. Intellectual courage and honesty, imagination and fine critical judgment, combined with extraordinary industry, allowed him to achieve a rare measure of success in scientific investigation in a short life.

JOHN P. PETERS

YALE MEDICAL SCHOOL

SCIENTIFIC EVENTS

THE FARADAY CENTENARY

IT is reported in *Nature* that, in response to the invitation of the Royal Institution, representatives of many scientific and technical societies met in the famous lecture theater in Albemarle Street on February 5, to consider the preliminary arrangements for the celebration of the centenary of Faraday's great discovery of electromagnetic induction, which he made on August 28, 1831. Sir Arthur Keith was in the chair, and in opening the proceedings reminded those present that the Royal Institution was not only the scene of Faraday's labors, but it was also for more

than half a century his home. Sir William Bragg, director of the Royal Institution, said that the proposed celebrations had been in mind a long time, and in choosing the particular discovery of August, 1831, they were recalling one of Faraday's most important discoveries, on which rested a vast body of scientific and industrial development. The occasion would give the nation an opportunity of realizing the contributions to science and industry during the last hundred years. It was unlikely there would be another occasion so favorable and, if made a success, the centenary would encourage the people to go on with their work and brighten the whole outlook of the nation.

Among the speakers was Sir Ernest Rutherford, who not only approved the suggestions but also pointed out that in 1931 occurs the centenary of the birth of James Clerk Maxwell, who in a sense was Faraday's interpreter and put into mathematical form the latter's views. Colonel K. Edgcumbe, president of the Institution of Electrical Engineers, Sir John Snell, Sir William Pope, Mr. D. N. Dunlop, Sir John Reith, Colonel W. A. Vignoles and Professor J. L. Myres all promised the cooperation of the societies they represented. Professor Myres made the interesting announcement that the officers of the British Association were prepared to recommend to their council that the centenary meetings of the Association of 1931 should be held in London, and said they would be glad to do everything in their power to ensure that not only the intellectual descendants of Faraday himself, but also the large public interests which benefitted from the applications of those discoveries, should be represented. The meeting approved the appointment of two small committees to deal with the scientific and industrial sides of the celebration, which Sir William Bragg announced would probably take place in the third week of September, 1931.

THE HENRY LESTER INSTITUTE AND HOSPITAL

THE *British Medical Journal* announces that an Englishman, Mr. Henry Lester, who had spent the greater part of a long life as an architect and estate agent in Shanghai, died in 1927, and, by a will executed two years prior to his death, bequeathed the bulk of his large fortune to various schemes for the promotion of education, along British lines, amongst the Chinese of the city of his adoption. After the disbursement of certain specified legacies covering various medical and educational institutions in Shanghai, the residue of the estate is placed under the control of "The Lester Trust" in order to give effect to the directions of the testator. The trustees must always be British subjects ordinarily resident in Shanghai.

The clause in the will which will be of most interest to the medical profession is that dealing with "the establishment of an institute or institutes for the study of and instruction in the English language, of medical science, surgery, civil engineering, architecture and other useful and scientific knowledge." The trustees have decided to separate medical science from the purely technical subjects, and to proceed at once with the erection of a dignified building, equipped on the most modern lines, for research in medicine and surgery. Dr. H. G. Earle, formerly professor of physiology in the University of Hong-Kong, has been appointed as general adviser to the trust.

Directions are given that the institute "be open to all nationalities, but especially Chinese," that not less than Shanghai taels 400,000 (over $250,000) should be expended on the building and equipment, and that it "be known as the 'Henry Lester Institute' and by no other name." The total amount of the residuary estate is still unknown, but, when all the other bequests have been provided for, it is expected that there will be funds amply sufficient to staff and endow a school containing at least six main divisions. These divisions will comprise:

1. Medicine, including Tropical Medicine and Parasitology.
2. Pathology, including Bacteriology and Immunology.
3. Physiology, including Biochemistry, Pharmacology and Industrial Physiology.
4. Surgery, including Experimental Physiology.
5. Hygiene and Public Health.
6. Field Research and Statistics.

The heads of divisions are at present being recruited from British schools of medicine, and it is hoped that the junior posts will be largely filled by young Chinese who have been trained abroad.

Until the institute is built, equipped and organized the activities of the staff will be entirely confined to research; later on, it will be possible to initiate courses of curricula for post-graduate studies in public health, tropical medicine and surgery, and in the event of the institute becoming affiliated to the University of Hong-Kong, there will be no further necessity for Chinese students to travel thousands of miles in order to take the D.P.H. or D.T.M.

Another medical institution which will benefit by Mr. Lester's generosity is the Chinese Hospital, long associated with the London Missionary Society, situated in Shantung Road, at a distance of about a mile from the proposed site of the institute. The bequest of Shanghai taels 1,000,000 ($650,000), together with certain valuable properties, will be sufficient to rebuild and partly endow a hospital with accommodation for about 200 patients. The new building will be known as "The Lester Chinese Hospital," and

will be controlled, not by the Lester Trust, but by its present board of trustees, but the clinical facilities of the hospital will be utilized by the research staff of the institute, and a beginning has been made by the appointment of Dr. Gordon Thomson, F.R.C.S., head of the division of surgery in the Lester Institute, as honorary visiting surgeon to the Chinese Hospital.

THE ERADICATION OF LEPROSY IN THE PHILIPPINES

THE trustees of the Leonard Wood Memorial for the Eradication of Leprosy announced that May 1 has been selected as Philippine Day and that every town, city and village in the United States will be asked to join in this observance, which falls upon the anniversary of the Battle of Manila. On May 1, 1927, Major-General Wood appealed for the first time to the American people for a fund of $2,000,000 to eradicate leprosy in the Philippines, and on Philippine Day this year the trustees hope to complete this fund as a memorial.

At the first call, two years ago, more than half of the sum was contributed, and the construction of new buildings, of entire new units, and of one completely new leprosarium has already been begun at Culion, the Philippine leper colony. The funds are being expended in erecting laboratories, living quarters for the staff and receiving stations on other islands, as well as for increasing the personnel necessary to carrying on the work.

Using the Culion colony as an experimental station, the memorial fund looks forward to finding a cure and ultimately to wiping out the disease throughout the world. There are now about 3,000,000 lepers in the world, according to figures recently compiled. Of these, about 12,000 are in the Philippine Islands, and Culion, an island about 200 miles south of Manila, has facilities for about 6,000 of them.

Reports from Dr. H. Windsor Wade, the American leprologist at Culion, indicate increasing success in the use of the chaulmoogra oil treatment, by which it has been possible to check leprosy even in the fairly advanced stages. Experts are now experimenting with less painful methods of administering this cure. Dr. Wade asserts that 1,700 negative cases already have been returned to their homes as cured, eighty cases having left Culion in January and February of this year. It is hoped that the disease can be eradicated in ten years in the Philippines if the necessary funds are raised.

About $100,000 of the amount raised by this new appeal will be used in erecting an adequate building for saving the children of lepers, who are born clean. Leprosy is not hereditary. The present Children's Home at Culion can not accommodate another child.

The trustees of the Leonard Wood Memorial are James G. Harbord, chairman; Major-General Samuel McRoberts, Robert L. Bacon, Eversley Childs, Robert W. de Forest, Dr. John H. Finley, Charles E. Hughes, Arthur W. Page, Kermit Roosevelt, Colonel Henry L. Stimson and Owen D. Young. The headquarters of the memorial are at 1 Madison Avenue.

AN AGRICULTURAL SURVEY

A NATION-WIDE study of the agricultural industries, requiring five years similar to the survey made by the Hoover Committee on Waste in Industry, is planned by the American Engineering Council. The council hopes to undertake the survey in cooperation with the American Society of Agricultural Engineers, according to an announcement made by Lawrence W. Wallace, executive secretary of the council. He says:

> Agriculture should industrialize its operations to the point where it can produce enough in one hour to exchange in the markets of the world for that which is produced in the same time. Agriculture can not be content, as now, to exchange products requiring 2.18 hours to produce for manufactured commodities made in one hour.
>
> Farm management as broad in its conception and execution as the best in industry and commerce realizes returns comparable with those of industry and commerce. Output per worker and not output per acre, is the important thing. Increased yield, and therefore increased income per worker, comes through the use of more power and machinery. Industrial methods and practices when intelligently adapted to agriculture are profitable devices.
>
> The proposed analysis of the agricultural situation is designed to point the way to practical and measurable standards of agricultural management; to an understanding of the interrelation and interdependence of agriculture, commerce and industry; to better agricultural financing and credits; to improved marketing facilities and results; to lower unit costs of production; to the elimination of avoidable waste in farm activities and products; to improved rural conditions through greater use of power and mechanical equipment, and to larger net returns and high standards of living for those engaged in the agricultural industry.
>
> The machinery of agricultural financing and credits requires complete revision. Attention should be given to the subject of capital investment, credits in relation to farm turnover, the financing of agricultural production on earnings, as contrasted to pledging basic capital.
>
> The program proposed will require five years to execute with scope and thoroughness. It will be comprehensive and all-embracing. It should be so, because no such study has been made, and, furthermore, only by an inclusive survey can an intelligent perspective be obtained. Its execution will require a thorough search of all authoritative literature, consultation with experts in many lines of activity and extensive and original field work.

MOTION PICTURE FILMS OF MEXICAN OIL FIELDS

"THROUGH the Oil Fields of Mexico" is the title of a new educational motion picture film prepared by the Department of Commerce, through the U. S. Bureau of Mines in cooperation with one of the large oil-producing companies, and now released for distribution. The film, which is in three reels, visualizes the drilling of oil wells in the Mexican jungles and depicts the various stages in the transportation, storage and refining of petroleum in the sister republic to the south. Many picturesque scenes illustrating Mexican life and customs and numerous striking scenic effects appear in the film, which was produced under the direct supervision of the Bureau of Mines. The location of the principal Mexican oil fields is made plain by the use of specially-drawn maps.

The first scenes show what has been called the "Hill of Tar," where the seeping of oil through the surface first called attention to the petroleum possibilities of Mexico. Next follow scenes of the Cerro la Pez well, the first commercial oil well in Mexico, which attracted the pioneers of the industry. A glimpse of the first oil-burning locomotive to be operated in that country is shown.

Views are presented of the Cerro Azul camp on the site of one of the richest oil pools of history. Here it was that in 1916 the Cerro Azul No. 4 well was drilled in, probably the most spectacular and best-known oil well in the world.

Especially attractive are the scenes showing the snow-capped peak of Orizaba, towering to a height of 18,000 feet, and the mountains, including the famous Popocatapetl, overlooking the Mexican capital. Quaint bits are introduced showing typical Mexican village markets; Mexican women carrying water jars upon their heads; the use of the humble burro for transport, etc.

It is pointed out that one and a quarter billion barrels of oil have been produced in Mexico and that one and one half billion dollars, much of which is American capital, have been spent by the industry in the recovery and handling of Mexican petroleum.

Copies of the film "Through the Oil Fields of Mexico" may be obtained for exhibition purposes by addressing the Pittsburgh Experiment Station of the U. S. Bureau of Mines, Pittsburgh, Pa. No charge is made for the use of the film, but the exhibitor is asked to pay the costs of transportation both ways.

SCIENTIFIC NOTES AND NEWS

DR. HENRY P. WALCOTT, who celebrated his ninetieth birthday on December 23, resigned as president of the Massachusetts General Hospital, Boston, at the annual meeting of the trustees on February 6, and was elected honorary president. The following resolution in tribute to his work was adopted at the meeting: "Fortunate indeed the institution which for more than a third of a century can command the devoted interest of so distinguished a citizen."

THE formal presentation of the Distinguished Flying Crosses, awarded by Act of Congress, approved December 18, 1928, to Mr. Orville Wright and posthumously to his brother, Wilbur Wright, was made on February 27 by the Secretary of War. The citation accompanying the award to Mr. Orville Wright reads: "Mr. Orville Wright. By his vision, perseverance, courage and skill, he, in collaboration with his brother, Wilbur Wright, designed, constructed and operated the airplane which at Kitty Hawk, North Carolina, December 17, 1903, made the first successful flight under its own power and carrying a human operator, thereby making possible the achievements which are now stirring the emotions and pride of the world." The posthumous award to Wilbur Wright was in similar terms.

PROFESSOR A. L. KROEBER, chairman of the department of anthropology of the University of California, has been elected a fellow of the Royal Anthropological Institute of Great Britain and Ireland.

MAURICE HOLLAND, director of the division of engineering and industrial research of the National Research Council, has been elected to membership in the Masaryk Academy of Prague.

THE Chancellor's medal of the University of Buffalo was conferred at the convocation exercises on February 22 on John J. Albright for his work in hydro development and as a patron of art.

CARL B. EIELSON, of Hatton, N. D., pilot for Captain G. H. Wilkins on his North Pole flight, has been awarded the Harmon trophy for 1928, given to the flyer making the greatest contribution to aviation during the year.

SIR GEORGE HUBERT WILKINS, who arrived in Havana on March 9, was awarded the Grand medal of the Cuban Geographical Society for the most noteworthy exploration of the year, in a reception at the Academy of Science. With him aboard the steamer *Ebro* were his Antarctic companions, Carl Ben Eielson, Orville H. Porter and Joseph E. Crosson. The explorers were welcomed by Cuban government officers and the staff of the British Embassy.

THE *British Medical Journal* reports that the Swiney prize for 1929 has been awarded by the ad

judicators, the Royal Society of Arts and the Royal College of Physicians, to Dr. Sydney Smith, Regius professor of forensic medicine in the University of Edinburgh, for his work, "Forensic Medicine." Dr. Swiney, who died in 1844, left a sum of money to the Royal Society of Arts to provide a prize every fifth year for the best published work on jurisprudence. The prize, which consists of £100 and a silver cup of the same value, was offered this year on the eighty-fifth anniversary of the testator's death for a work on medical jurisprudence.

Nature reports that the Council of the Institution of Naval Architects has awarded a premium for the year 1928 to Lieutenant-Colonel V. C. Richmond for his paper on "Some Modern Developments in Rigid Airship Construction," and a joint premium to Mr. E. Leslie Champness and Mr. Frank McAlister for their paper, "Further Notes on the Relative Strength of Fine and Full Cargo Vessels." The premiums will be presented on March 20 at the opening of the annual general meetings.

OFFICERS of the Royal Astronomical Society for the present year have been elected as follows: *President,* Dr. A. C. D. Crommelin; *Vice-presidents,* Sir Frank Dyson, Dr. E. B. Knobel, Professor H. F. Newall and the Reverend T. E. R. Phillips; *Treasurer,* Mr. J. H. Reynolds; *Secretaries,* Professor Herbert Dingle and Dr. H. Knox-Shaw; *Foreign Secretary,* Professor H. H. Turner.

COLONEL CHARLES A. LINDBERGH has been appointed a technical adviser to the aeronautics branch of the Department of Commerce. He will hold no statutory position with a regular salary attached, but will be available when needed by the department for advice, on matters of airway regulation, accident prevention, airport construction, airway equipment, airway mapping and aeronautical research.

DR. JAMES S. MCLESTER, professor of medicine in the University of Alabama, has been appointed to succeed the late Dr. Samuel W. Welch, of Talladega, former State Health Officer, as the representative of the south on the Council on Medical Education and Hospitals of the American Medical Association.

LAWRENCE W. BASS has been appointed executive assistant at the Mellon Institute, Pittsburgh. He was formerly an associate in the division of chemistry of the Rockefeller Institute for Medical Research.

AT Harvard University leaves of absence during part or all of the year 1929–30 have been granted to Associate Professor Arthur Edwin Norton, mechanical engineering; Assistant Professor Harlan True Stetson, of the Observatory, and Associate Professor Hubert L. Clark, curator of the Museum of Comparative Zoology.

A PORTRAIT of James E. Rice, professor of poultry husbandry in the college of agriculture of Cornell University since 1907, was presented to the university on February 12 in a ceremony in the poultry building. The portrait, done by Professor Olaf M. Brauner, was presented by Dr. Gustave F. Heuser and was accepted on behalf of the university by Dean William A. Hammond. Dean Albert R. Mann presided. A scroll of all the donors was also presented by Dean Mann. The portrait has been hung in the poultry building.

DR. W. K. FISHER, director of the Hopkins Marine Station, Pacific Grove, California, will leave about April 1 to join the Pinchot South Sea Expedition, to be absent until the end of the summer. During the spring quarter Dr. Harold Heath will be acting director of the station and during the summer quarter, Dr. Charles Vincent Taylor.

RALPH S. HOSMER has been granted sabbatical leave of absence from Cornell University for the second term of the present academic year. He expects to work on a book on the history of forestry.

DR. RACHEL E. HOFFSTADT, of the department of bacteriology of the University of Washington, was recently awarded the Mary Pemberton Nourse Memorial fellowship and will spend next year in Europe in study and research in immunology.

J. E. WILLIAMSON, the originator of underseas photography, has been placed at the head of an expedition sent out by the Field Museum of Natural History to photograph marine life in the Bahamas. Mr. Williamson has a fleet of twelve vessels, each designed for a particular phase of the expedition. The chief objective will be to obtain material for ten underseas habitat groups of fishes at the Field Museum. Photographs, motion pictures and color sketches will be made.

DR. JOSEPH C. AUB, associate professor of medicine in the Harvard Medical School, will deliver the sixth Harvey Society lecture at the New York Academy of Medicine on Thursday evening, March 21. His subject will be "Calcium and Phosphorus Metabolism."

DR. G. W. STEWART, professor of physics at the University of Iowa, gave a series of lectures before the departments of physics and chemistry at Morningside College, Sioux City, Iowa, on February 14 and 15. The lectures presented the salient features of Professor Stewart's work on "X-ray Diffraction in Liquids."

DR. IRVING LANGMUIR, associate director of the research laboratory of the General Electric Company, president of the American Chemical Society, spoke on March 8 before the New England section of the society on "Contact between Oxygen and Hydrogen in Contact with a Tungsten Filament—an Example of Passivity."

DR. ARTHUR BYRON COBB, professor of mathematics in the University of Illinois, will lecture at the University of Chicago during the summer session.

DR. P. J. HANZLIK, professor of pharmacology, Stanford University School of Medicine, San Francisco, addressed the Portland Academy of Medicine on January 11 on "Antirheumatic Remedies," and the Medical History Society of the University of Oregon Medical School on January 12, on "The One Hundred and Twenty-fifth Anniversary of the Discovery of Morphine by Sertuerner."

DR. J. C. MCLENNAN, professor of physics in the University of Toronto, delivered on February 23 an address to the Royal Canadian Institute on "The Relation of Light to Matter."

PROFESSOR HERBERT S. PHILBRICK, head of the department of mechanical engineering at Northwestern University, will give the commencement address at Colby College at the 1929 commencement.

DR. CHAS. N. GOULD, director of the Oklahoma Geological Survey, delivered a lecture at the Brooklyn Institute of Arts and Sciences on February 18 on "Geology in Oil Finding."

ABOUT eighty presidents of various national organizations have signed a manifesto inviting Norwegians all over the world to subscribe to a Roald Amundsen memorial fund, which is to be established on the initiative of the Norwegian Press Association, the University of Oslo, the Academy of Sciences and the Geographical Society. The income from the fund will be devoted to the promotion of geographical exploration.

IT is proposed to commemorate the memory of Benjamin Neeve Peach, who died in 1926, and of John Horne, his fellow worker, who died in 1928, by the erection of a bronze plaque to be placed in the Royal Scottish Museum in Edinburgh. A committee has been appointed to raise funds for the memorial, of which R. A. Sampson is chairman, and which includes delegates from the Geological Survey of Great Britain, the Royal Scottish Museum, the geological departments of Scottish universities, the Royal Society of Edinburgh, the Scottish Geographical Society, the Royal Physical Society of Edinburgh and the Geological Societies of Edinburgh and Glasgow.

DR. CHAUNCEY J. V. PETTIBONE, associate professor of physiological chemistry in the University of Minnesota, died by suicide at Minneapolis. Dr. Pettibone had been in ill health.

ALEXANDER LEWIS JENKINS, head of the department of mechanical engineering at the University of Cincinnati, died on March 8.

EDWARD HOWE FORBUSH, for thirty-eight years state ornithologist of Massachusetts until his retirement a year ago, died on March 9 at the age of seventy years.

THE death is announced of Miss Abbie Elizabeth Tucker, for thirteen years instructor in the astronomical department of Smith College. For the last thirty-five years Miss Tucker had conducted a college dormitory.

THE seventh annual symposium of Colloidal Chemistry will be held this year at the Johns Hopkins University, Baltimore, Md., June 20–22, inclusive. Professor F. G. Donnan, of University College, London, will be the guest of honor. Visitors may secure rooms and meals in the University Dormitory at a total cost of $6.00 for the entire meeting. Inasmuch as the accommodation of the dormitory is limited to one hundred and fifty, early arrangements are advisable. Address all letters of inquiry to W. A. Patrick, Johns Hopkins University, Baltimore, Maryland.

RAY LYMAN WILBUR, secretary of the interior, will address the New York Health Conference at the Hotels Roosevelt and Biltmore, New York City on March 14 and 15. Other speakers will include Surgeon-General Hugh S. Cumming, Dr. William H. Welch, of the Johns Hopkins University and Dr. Shirley W. Wynne and Matthias Nicoll, Jr., City and State Health Commissioners, respectively. The conference will be under the joint auspices of the United States Public Health Service, the State Department of Health, the City Department of Health, the State Medical Society, the Milbank Memorial Fund, the State Charities Aid Association and the Community Health Council of the Bellevue-Yorkville Health Demonstration.

THE fourth spring meeting of the Oklahoma Academy of Science will be held in the Arbuckle Mountains on May 10 and 11. Field excursions will be held on trees, flowers, grasses, mosses, ferns, insects, birds, vertebrates, ecology, stratigraphy, structural geology and paleontology, and addresses will be given on botanical gardens, grasses, poisonous animals, plant diseases, stars and the geology of the Arbuckle Mountains.

A CONFERENCE on the possibilities of oil and gas power will be held as the second national meeting of the Oil and Gas Power Division of the American Society of Mechanical Engineers at Pennsylvania State College in conjunction with the third annual oil and power conference of the college from June 24 to 27. One of the features will be an exhibition of oil engines, parts and accessories. Over twenty companies participated in the exhibit last year, the first of its kind ever held in the United States, the total attendance being over 500. Practically every representative manufacturer of Diesel-engines is expected to attend the conference. Another feature will be a discussion of uniform fuel-oil specification standards.

A SPECIAL program is being arranged for geological members of the British Association for the Advancement of Science in connection with the South African meeting next summer that they may cooperate with the International Geological Congress, which will be meeting in Pretoria concurrently with the association in Johannesburg. The agricultural members will be afforded opportunity for meetings with their colleagues in the Pan-African Agricultural and Veterinary Congress, which is to be sitting in Pretoria at the same time. After the meetings the majority of the visiting members, expected to number about 400, are to divide into three main parties. Each of these visits the Victoria Falls, and two subsequently make extended journeys through the Union territory, visiting the eastern Transvaal and Lourenço Marques, Portuguese East Africa, and ending their journeys at Durban and Cape Town, respectively. The third main party is to proceed from the Victoria Falls to Beira, visiting *en route* the ruins at Great Zimbabwe, where it is hoped that Miss Caton-Thompson will have brought to a successful issue the investigation of the ancient remains which she is about to undertake at the instance of the association.

CABLE advices from the *Carnegie* after her arrival at Callao on January 14 state that on January 8 a new submarine ridge, which has been named Merriam Ridge, was discovered. At the point of crossing, Merriam Ridge is ten miles wide and rises 3,000 meters above the 4,000-meter depth on either side. The top of the ridge, in latitude 24° 57′ S. and longitude 82° 15′ W., is at 1,168 meters, this value being checked by three sounding methods, namely, sonic, wire and thermometer, to within 20 meters. When 60 miles west of Callao, the surface temperature, which had been at 21.5° C., dropped to 19° C. and remained at that value until arrival at Callao. Captain Ault's report shows that the activities in the various observational programs are being successfully continued, the work between Easter Island and Callao (December 12, 1928, to January 14, 1929) including 38 declination stations, 15 horizontal-intensity and inclination stations, 17 oceanographic stations, 72 sonic depth stations, 12 pilot balloon flights, 25 complete photographic 24-hour potential-gradient records, 4 24-hour series of other atmospheric-electric observations, 20 biological stations, 6 evaporation series. The vessel is expected to leave Callao about February 3 *en route* to Papeete, Tahiti, Society Islands, where she is due to arrive early in March.

THE Premier of Ontario, Mr. Ferguson, at a luncheon attended by one hundred members of the Ontario Research Foundation, announced that he would ask the Provincial Legislature to vote a dollar for each dollar subscribed privately toward the foundation funds. Private subscriptions already amount to $1,600,000 (£320,000). The Dominion government also has been considering the recommendations of Mr. J. H. Grisdale, deputy minister of agriculture, who represented Canada on the Empire Research Agricultural Committee, that it should participate in an empire-wide scheme of agricultural research, involving the establishment of eight new bureaus. It is understood that the government is ready to seek the necessary financial authority from Parliament for the Dominion's contribution.

UNIVERSITY AND EDUCATIONAL NOTES

A NEW Science Building at University and Exposition Park, Los Angeles, housing the departments of physics, botany and zoology on its first three floors, respectively, has been completed at the University of Southern California, at a cost of approximately $350,000. Ample space on the fourth floor of the building has been given over to experimental marine biology and survey work, with installation of running sea-water aquaria, research laboratories and other appropriate facilities promoting course and graduate work. Invertebrate zoology and marine survey courses for credit are included in the summer school offerings, and space and facilities for research may be had by a limited number of independent investigators who have definite problems in hand. Inquiries should be addressed to Professor Francis Marsh Baldwin, director of experimental biology, in care of the university.

MRS. HELEN M. A. BALDWIN, widow of Mr. C. Kemble Baldwin, who was vice-president of the Robins Conveying Belt Company, has presented to Lehigh University the sum of $10,000, to be supplemented on her death by an additional $15,000, for the

establishment of the C. Kemble Baldwin Foundation for Research and Instruction in Aeronautics. Under the terms of the gift the income of the fund may be employed for research in any field of technology having a bearing on aeronautics.

THE N. V. Potash Export My., New York and Amsterdam, Holland, have established a five-year fellowship at the Massachusetts Agricultural College Experiment Station for investigations on the relation of fertilizers to asparagus culture. The work will be under the direction of Professor V. A. Tiedjens at the Market Garden Field Station at Waltham, and will be conducted on four definite soil types.

MRS. GEORGE E. WARREN, of Boston, who was recently elected a trustee of Rollins College, and her sister, Mrs. Homer Gage, of Worcester, have made a gift of $100,000 to the college for construction of a college building.

WILLIAM D. ENNIS, director of research of the Technical Advisory Corporation of New York, has been appointed to fill the newly established chair of economics and engineering at Stevens Institute. The chair is a memorial to the late president, Dr. Alexander D. Humphreys. Gifts amounting to $50,000 toward its endowment have been recently announced.

DR. A. N. BANTA, of the Carnegie Institution of Washington, at Cold Spring Harbor, Long Island, is acting professor of experimental biology for the present semester at Brown University, in place of Professor J. Walter Wilson, who is on leave of absence in New Mexico.

DISCUSSION

THE SPECTRUM OF THE AURORA BOREALIS

ACCORDING to the hypothesis proposed by Cario and the writer, the α bands of the nitrogen molecule that arise in the nitrogen afterglow can be accounted for by ascribing their excitation to collisions between metastable molecules of nitrogen and metastable atoms in the ^2D and ^2P levels. By using similar considerations it has been possible to account for some of the radiation of the aurora for which no satisfactory explanation has as yet been given. Although the spectra that can be explained in this manner are among the weakest in the aurora, they are of interest because of the remarkable similarity between the processes by which they are excited and those by which the α bands in the nitrogen afterglow are excited. In this short note only two of these unexplained lines will be considered, although some of the remaining lines readily fit a similar explanation. Their discussion will, however, be postponed until a full account of this work is published.

The formation of metastable molecules of nitrogen in the aurora can be readily accounted for. The second positive bands of nitrogen, corresponding to the transitions C–B, are quite strong in the aurora. The first two or three B levels are the final levels of the molecule corresponding to the strongest of these bands. The first positive bands that are radiated with these B levels as the initial states, will have as their final levels the first two or three A levels. These first positive bands lie so far in the red that their observations in the aurora would be a very difficult task. In the above manner we have accounted for the presence in the aurora of nitrogen molecules in the A_1 and A_0 levels, these levels being metastable.

Now the energy of the nitrogen atom in the ^2D and ^2P levels differs from the energy in the ^4S ground state by 2.37 and 3.56 volts respectively. Granting the presence in the aurora of metastable nitrogen atoms in the ^2P level, it is seen that most of these should radiate in a transition from the ^2P to the ^2D level, and only a few of these ^2P atoms should give up their energies by collision. Radiation corresponding to these transitions will fall at about 1.04 μ so that its observation, either in the aurora or in active nitrogen, is practically impossible with our present methods. Similar arguments can be applied to atomic oxygen. Here, however, the line corresponding to the transition $^1S_0$–$^1D_2$ is now known to be the aurora green line. We can conclude from the behavior of atomic oxygen in the aurora that the transition between the ^2P and ^2D levels in nitrogen should be much more probable than the transitions between the ^2P and ^4S or the ^2D and ^4S levels. In discussing the results of collisions between nitrogen molecules it is necessary therefore to consider only the ^2D metastable atoms. A similar argument will of course apply to collisions between atomic oxygen and metastable nitrogen molecules.

The difference B_6–A_0 in the nitrogen molecule corresponds to an energy of 2.38 volts. One should therefore expect transitions in the aurora having B_6 as their initial level. Two weak lines having wavelengths of 5176 A and 5149 A have been observed in the aurora by early investigators. The transition B_6–A_0 gives rise to a band of which the first head lies at 5178 A. The transition B_7–A_1 yields a band having its first head at 5152. It is therefore proposed that these bands are excited in the aurora by collisions of the second kind between ^2D nitrogen atoms and metastable nitrogen molecules in the A_0 and A_1 levels. This explanation is in complete

agreement with the discussion given in the first part of this note.

In a recent discussion of the aurora green line Sommer suggested that the lines 5176 and 5149 correspond to the transition ^2D–^4S. The wave number difference between 5176 and 5149 is 101 cm^{-1}, and according to Compton and Boyce the difference between the ^2D levels is only 5 cms^{-1}. It is therefore difficult to see how the assignment of Sommer can be correct. In addition to this objection it should be noted that the most probable location of the lines corresponding to the transition ^2D–^4S is at about 5207 A, and the difference between this and the two lines mentioned above is too large to be ascribed to experimental error.

Three other bands, 5925, 6465 and 6323, have been explained by the writer by considering collisions between metastable nitrogen molecules and metastable oxygen atoms. A preliminary account of this has been given in a paper before the February meeting of the American Physical Society.

We wish further to call attention to a striking characteristic of the five α bands that have been mentioned in this note. Normally, the bands each possess several heads. In the aurora, however, the bands appear with only a single head. Such curtailed bands have been observed by the author in some experiments in which the aurora green line was excited in active nitrogen. This peculiar development of the α bands is, however, not understood at the present time and a further study of this phenomenon is to be made.

JOSEPH KAPLAN

DEPARTMENT OF PHYSICS,
UNIVERSITY OF CALIFORNIA AT LOS ANGELES,
FEBRUARY 5, 1929

SOUNDS REPORTED ACCOMPANYING THE FALL OF A METEOR

THE appearance of a large meteor coming to the earth or so near to the earth as to be both seen and heard, although not entirely unusual, is nevertheless of such interest as to justify permanent record. On June 23, 1928, such a meteor appeared in southwest Texas. Although falling in daytime on a bright afternoon, this meteor was of such brilliancy as to attract wide attention and to be seen for two or three hundred miles. It appeared in the sky, according to the most reliable observations, at or near 4:40 in the afternoon, and traveling with great swiftness in a northeasterly direction, disappeared without, so far as evidence has been obtained, reaching the earth.

The general appearance of the meteor is given by several observers. All agree that it flashed out in the sky to great brightness suddenly, and that its course was traversed in a few seconds. All who were near observers agree that although approaching the earth it ceased to be visible or disappeared by explosion before reaching the ground. The meteor is variously described as "a ball of fire shooting across the sky," as having "the appearance of a skyrocket," and as "a dark ball with a fiery tail." Phenomena usual to meteors were observed, including light, sound and a cloud or train.

To those who were near at hand the light of the meteor appeared as "brilliant," "incandescent," "similar to the light of the sun," "not blinding but very bright," "as bright as the sun." One observer says that although he was looking through smoked glasses the light of the meteor was a strain to the eye. Some describe the light as having a play of colors; others failed to observe any such variation in color. To those at a greater distance the light appeared for the most part a dull red. Obviously the condition under which the light was observed and the distance from the meteor affected its appearance. Those who were looking towards the sun seem to have seen the meteor with essentially the same distinctness and as showing the same brilliancy as those who were looking away from the sun.

The cloud which attended the meteor was seen from almost as great distances as was the light itself, and was seen in fact by many more people, for while the flash of light marking the path of the meteor lasted no more than one or two seconds, the cloud floating in the clear sky continued visible from some points of observation for more than an hour. This cloud doubtless appeared different from different viewpoints, and it is variously described. By those who saw it earliest the cloud is described as being at first a wisp or thread of smoke forming in the path of the meteor and gradually spreading into a cloud. It is described by all observers as light in color and cloud-like in appearance. Observations on the duration of the cloud are as follows: From localities east (looking toward the sun), seven to ten minutes, ten to twenty minutes, thirty minutes, thirty to forty-five minutes, nearly an hour; from localities west (not looking toward the sun), one hour and twenty minutes, and "until sundown"—about three hours. The length of the cloud according to the best measurements obtainable approximated fifteen miles.

Instrumental measurements on the cloud supplemented by approximate records as to the time required for the explosive sound to reach the earth indicate that at the time of final disappearance from view the meteor was between five and nine miles above the earth. The rate of travel of the meteor based upon an estimated duration of the flash of light and the length of the cloud appears to have been between five and seven and a half miles per second.

SOUND

Two distinct sounds accompanied the passage of the meteor. One of these was the explosive noise often heard in this connection. This sound was of such intensity as to distinctly jar the buildings and to cause the rattling of windows at localities over an area approximating forty miles in east-west by sixty miles in north-south direction. The time required for this explosive sound to reach the earth varied from possibly thirty seconds for those immediately under the meteor at the termination of its visible course to one and a half or two minutes for those at a distance of fifteen or twenty miles from its overhead position. Aside from the intensity no other unusual features are reported in connection with this explosive sound.

The second sound reported to accompany the meteor is wholly unexplained, and this note is written chiefly for the purpose of recording these reports. This unexplained sound is described as a whizzing and whining sound and as like the passage of a skyrocket through the air, and as a "shhh" sound. In all instances this sound is reported as having occurred instantaneously with the flash of light. Reports of this noise come from observers at various places, some being as much as two hundred miles apart, and one hundred miles or more away from the locality where the meteor was overhead. The following observations indicate how definitely this noise is reported. The distances given in the following notes are from Laguna, near which place the meteor was overhead. An observer at Leakey, twenty-five miles northeast of Laguna, states that at the time of the appearance of the meteor he was repairing a wire fence and was stooping over close to the ground fastening the lower wires of the fence. In this position he heard distinctly a whizzing sound which he at first supposed to be made an aeroplane with the engine shut off preparatory to lighting in an aeroplane field nearby. Upon looking up, however, he saw the flash of the meteor. An observer at Hondo, about fifty miles east of Laguna, says: "I saw it fall, but would not have seen it had I not been attracted by the sound it made. It sounded 'shhh,' and shot across the sky from southeast to northwest." A lady driving southeastward by car some seventy-five miles northeast of Laguna writes: "My husband, daughter and myself were driving from Kerrville to San Antonio that Saturday afternoon. I heard a buzzing noise, and looking out of the car window saw a big ball of fire shooting across the sky in a northwest direction. I called my husband and daughter's attention to it and before they could get to the west side of the car the ball of fire was nearly all gone but they saw the sparks and smoke that it left behind." An observer at Winter Haven, sixty miles south of Laguna, says: "I was sitting with my back to the northwest when I heard a noise—a hiss or a whiz. A dog standing near growled and then barked." A lady at Uvalde relates that she was lying on the bed by her north window when she heard a "whining, whistling noise" which continued for a second or so before she looked up. Just after turning her head to look out of the window there was a long flash of light across the sky, so quick she was not sure at which end it began and at which it finished. She got the impression of two long, slender streaks of flame with a slit between them. Almost immediately after the flash, white smoke began to form along the line of the flash. The whining noise continued for an appreciable interval after the flash. The explosive sound of the meteor was heard one and one half or two minutes later. An observer near San Antonio, and about seventy-five miles east of Laguna, "heard a sizzling noise overhead and looking up saw a very brilliant object tearing through the air."

The writer has not been able to search the literature. However, in at least one previous instance a similar noise in connection with the fall of a meteor is recorded, this being a meteor which fell on October 1, 1917.[1] Since the rate of travel of a meteor is much in excess of the rate of travel of sound, it is impossible that the sound wave propagated in the usual way could have arrived coincidently with the light from the meteor. As already noted this noise is reported coincident with the flash at localities as much as two hundred miles apart. One must either consider some other possible explanation for the noise or must discard a considerable number of observations made independently, at various places and under varying conditions, all of the observations being in essential agreement. Any suggestions that may be made explaining such reported sound in connection with the meteor will be welcomed.

E. H. SELLARDS

UNIVERSITY OF TEXAS

OBSERVATIONS OF GREEN FLASH

FRANK T. DAVIES, physicist on board the *City of New York*, en route to the Antarctic regions with the Byrd Antarctic Expedition, reports as follows on a green flash observed off Bermuda on the evening of August 29, 1928: "At sunset a green flash was observed very clearly by the writer, Captain Melville and about six members of the crew. Meteorological conditions: Weather, fine; clouds, fairly high, stratocumulus about 0.3, nearly all circling around horizon and leaving western horizon clear except for smoki-

[1] J. A. Udden, "The Texas Meteor of October 1, 1917." University of Texas Bulletin 1772, page 45; also SCIENCE, December 21, 1918, pp. 616–17.

ness; wind southwesterly, freshening during night and bringing short-duration rain-squall from west at 4 A. M., August 30. Very smoky dull-red sunset; as sun was about five sixths set, it turned yellow and then merged into green for about two seconds before tip sank under horizon. It did not look to me like a flash but a definite change from yellow to green lasting about two to three seconds."

JNO. A. FLEMING

WINTER ACTIVITY OF THE ROOTS OF PERENNIAL WEEDS

IN a recent number of SCIENCE, F. J. Crider[1] recorded that roots of certain plants commonly thought of as having a dormant period in southern Arizona continued to grow throughout the cooler season. During the winter of 1924–25 at Iowa State College while the writer[2] was excavating roots of the Canada thistle (*Cirsium arvense*) for chemical analysis, he noted the behavior of the roots of this plant with reference to the activity of the buds upon the horizontal regenerative roots.

Buds which grew into shoots as long as the ground was warm continued to develop upon the horizontal roots of the Canada thistle from the middle of September until the middle of November. As these shoots appeared above ground they formed rosettes only, and did not send up stalks. When the rosettes were killed by frost early in November, those shoots which were still developing in the as yet unfrozen ground were unaffected. The part of the shoots between the roots and the surface of the soil in these fall shoots was, however, slender and delicate and sparsely covered with long black scales. The freezing of the soil killed these shoots quickly, and after the middle of December no uninjured shoots were found upon the roots taken from cold but incompletely frozen soil. Regions of underground stem that had been killed by temporary freezing of the surface of the soil were black and partly decomposed down to the depth of penetration of the frost, but were succulent below. In some cases they had died back to their connection with the horizontal root. No new shoots were formed in December, and the ground was frozen solid to a depth of 50 cm during the latter part of this month. On January 3, 1925, when more samples were being taken for analysis, the latent buds on the larger roots of the Canada thistle were noticeably increased in size over what they had been three weeks previously. The soil was frozen so that it had to be removed with a pick and mattock and taken to the laboratory to be thawed out. This made possible rapid and accurate observation of the root systems and conditions of the shoots upon the roots.

A break across the root at the point of attachment of the bud revealed ice crystals in the intercellular spaces, both in the root and in the bud. By the middle of January similar buds on other roots had developed into thick, vigorous, pointed shoots 15 to 20 mm long and 3 to 5 mm in diameter, with heavy, whitish scales completely covering the outside of the shoot. These were not fall shoots arrested by cold, because they were more than twice as large in cross section as the lower parts of the slender fall shoots which were still intact upon the same root and which were connected by black dead stems to the rosettes above. The new shoots had a free, sharp, growing point. The lower part of the shoots produced from September to November remained white because they were frozen during the cold period of December, 1924, and had had no chance to disintegrate.

According to Lund and Rostrup,[3] who have made an exhaustive study of the root systems of this plant, the roots of the Canada thistle radiate from a downward bend of a regenerative and storage root. They grow horizontally for one to two meters before they too turn down. This process is repeated several times in a season. The observations of Lund and Rostrup have been found to hold for the conditions of the United States as well as Denmark, but these authors seem to have made no study of the roots during the winter and hence failed to note the development of the buds upon the roots, or the new horizontal roots upon the old storage organs.

On February 3, 1926, new, light-colored, horizontal roots only 1 to 1.5 mm in diameter and 10 to 20 cm long were found upon old roots, and upon the newer downward bends of the last roots of 1924, where they had been entirely absent from similar roots in December, 1924. At this same time, February 3, the shoots were from 4 to 7 cm long and from 5 to 7 mm in diameter, greatly exceeding the size of the shoots on the roots taken in January from the frozen ground. There were also more buds on the "kinks" of the horizontal roots. The shoots and roots were succulent when not frozen, and when frozen were full of ice crystals in the intercellular spaces. The remaining parts of the fall shoots quickly blackened upon thawing and were not turgid. The horizontal roots which

[1] F. J. Crider, "Winter Root Growth of Plants," SCIENCE, 68: 403–4, 1928.

[2] Charles F. Rogers, "Carbohydrate Metabolism in the Roots of the Canada Thistle." Thesis, Iowa State College, 1925.

[3] Samsøe Lund, and E. Rostrup, "Marktidselem, *Cirsium arvense* en monografi." *K. D. Vidensk. Selsk. Skr.*, 6R, n–m. Afd. X, 3: 1–152. 1901. Résumé en française, pp. 153–165.

had sprung from the older regenerative roots were by March 3, 1925, 2 mm in diameter, 15 to 30 cm long and creamy white in color. They could easily be distinguished from the old roots by their position, their size, color and freedom from "kinks," regenerative buds and shoots. On March 15 the soil was no longer frozen solid, and development of the whole root system became more rapid. Green leaves of the thistle appeared above the surface of the soil on April 12, 1925, and by this time the fall shoots had blackened and died back to the junction with the horizontal roots. In no case had buds in the axils of the scales on the fall shoots developed into new stems. The roots of two other perennial weeds, the common wild morning-glory (*Convolvulus arvensis*) and a poverty weed, *Franseria tomentosa,* were studied throughout three winters from 1925 to 1928, at the Agricultural Experiment Station at Fort Collins, Colorado. Although the size of the roots of these latter plants is different from that of roots of the Canada thistle, their cycle of bud and root formation is similar in almost every respect to that described for *Cirsium arvense.*

CHARLES F. ROGERS
UNIVERSITY OF MINNESOTA

AN ARTIST LOOKS AT GORDONIA

THE writer had been much interested in many newspaper items about a rare plant which had been introduced in one or two Macon gardens, a native Georgia species discovered by the famous Bartram in his travels through eastern Georgia, a species now supposed to be almost extinct, save for a plant kept alive through the years in a northern botanical garden and the parent of the plants introduced in Macon. The name given in the press of "Gordonia Altamaha" had a romantic sound but otherwise meant nothing.

However, the artist had an opportunity to converse with a friend who is a distinguished horticulturist, and this conversation, which revealed further enchanting facts about the famous Gordonia, led to a desire to see and know better a rare plant and the still greater desire to paint that plant.

Realization is often the disappointment of imagination and the present case was no exception, a first glimpse of Gordonia conveying to the neophyte only that here was but a variety of the familiar "Cape Jasmine" plant. Gradually with the help of the horticulturist the plant's rare beauty began to reveal itself. The rich foliage was a delight, shading from a pale to a beautiful bronze green, the designs of the veined and pointed leaves, the smooth, almost blue-green stalks from which the leaves seemed to grow in clusters, the variety of greens in the leaves, the undersides sometimes a silvery tinge, and in some cases of an almost green-gold luster. The tops of the leaves were glossy but of varied shades of green, scarcely two leaves being of the same shade, the young leaves appearing a delicate pea color, while the more matured ranged from almost a blue-green through the yellow-greens to a real bronze tone. The play of sunlight and shadow on this varied foliage produced a beautiful effect.

Then the horticulturist pointed out a bud, apparently about the size of the common marble or agate. The bud appeared to grow from a main stem, nestled in leaves which grew out from beneath it in a star-like radiation, the young leaves atop the more matured. There seemed to be only the one blossom-bud on the entire plant, and when first seen it was of a delicate pale pea-green, shading to a decided light yellow in the top center. The artist preparing his materials sat down to watch the unfolding of the blossom, for it was said that the flower of the Gordonia opened, bloomed, folded and died in a single day. Forgetful of time, of the hot sun, of the prick of insects, the artist sat enthralled by the miracle unfolding before his eyes and tried desperately to catch some of its wonders on his sketch pad.

The bud split in three main divisions and seemed gradually to curl and spread back from the yellow center. The green seemed to recede into the stem, drawing the yellow with it. The yellow, as it followed, took on a deeper tinge underneath, while towards the center it grew pale and, as the blossom opened, a pure white appeared. Then, somewhat like the magnolia, the petals unfurled more, and instead of three there were five divisions, and in the heart of the white a dash of gold appeared. The main flower, except for the yellow-green and pale yellow of the under part, near the stem, was of the purest and most exquisite white imaginable. The flower had now spread to a size larger than that of the "Cape Jasmine," being almost the size of a small tea-cup. The edges of the five main petals ruffled and began to curl back, allowing the beautiful yellow gold of the heart to appear. The heart, as the petals now opened rather rapidly, was of a mushroom shape and appeared to consist of closely bunched stamens growing from the center with globular pistils producing the mushroom effect. This rounded top of the mushroom-like center was a brilliant golden yellow, while the stem section was of a golden orange tone. This center glowed like a jewel, and with the pristine white of the now unfolded petals the flower was indeed a thing of beauty. A faint, pleasing odor, hard to describe, emanated from the flower.

The flower was now at the height of its blooming and the artist completed his sketch, but even as the finishing touches were put on, the white petals began

to curl inward towards the golden heart. The yellow-green of the under-section of the petals now began to reappear as they folded together. Soon the golden mushroom-like center became hidden by the enfolding petals, then disappeared in the ball of white with its pale yellow under-side. The flower seemed to shrivel and shortly after the sinking sun threw the last glorious tinge on the summer twilight sky, the white globe which had been the lovely flower of the famous Gordonia dropped off the stem, leaving only a pale green scar in the heart of leaves, a scar scarcely seen, but eloquent relic of one of nature's dramas.

EDWARD S. SHORTER

ANTI-EVOLUTION IN NEW ENGLAND

THE following letter coming from Hartford, Connecticut, and signed by a well-known New England name may be of interest to readers of SCIENCE:

You may discontinue my subscription to Ecology.

Ecology now has articles from the standpoint of evolution; for instance Further Views on the Succession-Concept, H. A. Gleason, July, 1927. It is with regret that I do this. I have found a great deal about ecology in it. I have taken it ever since the beginning as I was one of the subscribers to the Plant World. I have no use for evolution and do not see how any intelligent person can have.

BARRINGTON MOORE

AN ANTI-VIVISECTION SCREED

THIS anonymous note reached me a few days ago following a very simple operation that I had. I thought possibly the readers of SCIENCE would be very much amused at this ebullition of temper. I take it that it is from a woman, and if so I pity her possible husband.

Why didn't you have the operation without anesthetic, so you could see how the animals feel, that you have tortured all these years? You will have an awful body in the next incarnation!

That notorious old French vivisector at the age of eighty in Paris, has acknowledged that no good has come of it, and that he knows it is not good for the students minds. You could do much good before you die, by expressing your self in like manner. You have one foot in the grave now, and the other on a banana peel, you old fiend.

The fun of the thing is that I have *never* been a research worker. The first laboratory of Medical Research was established in connection with Bellevue Hospital Medical School by Andrew Carnegie in 1884. By that time, my career was marked out for me very clearly as that of a clinical surgeon. I have never experimented on *any* animal, not even a mouse or a frog.

I shall keep my eye on that banana peel you may be sure.

W. W. KEEN

SPECIAL CORRESPONDENCE

THE STUDY OF GEOLOGY BY AEROPLANE

ON January 12, 1929, my class in "Sedimentation" at the University of Southern California took an aeroplane trip along and over the Whittier Hills and Santa Ana Mountains, east and southeast of Los Angeles, California. The plane, a four-passenger type, was supplied through the kindness of the Stoody Company. It is believed that this was perhaps the first use in the United States of an aeroplane by an entire geology class. Since each student was aloft an hour and a half, it has seemed worth while to record their impressions and to ask for suggestions from other schools that may be planning flights, or may perhaps have antedated this one.

The students had already spent a semester in studying the peneplained Triassic basement complex of quartzites and slates, shot with Jurassic intrusives and partly overlain by Jurassic (?) extrusives; as well as the Cretaceous and Eocene formations, chiefly heavy sandstones where exposed in the Santa Ana region. All the formations are tilted into an unsymmetrical anticline with its gentler dip to the southwest and complicated by a dome-like anticline striking north-south on the western flank of the major structure.

We were uncertain as to how much could be observed from the air during the time each student was allotted. Accordingly, directions were given to center attention on four points:

(1) A fault which runs along the entire southern front of the Whittier Hills.

(2) Terraces, due to the latest uplift, along the canyons of the Santa Ana Mountains.

(3) The contacts between Triassic and Cretaceous, Lower? Cretaceous and Upper Cretaceous, Upper Cretaceous and Martinez Eocene, Martinez and Domengine? Eocene.

(4) The great Perris peneplain to the northeast of the Santa Ana Mountains. This plain had never seemed to the students a base-leveled region, because, observed from the earth, the flatness is obscured by elevations, numerous, highly irregular in shape, and often five hundred feet high.

I accompanied each group of three. After the first gazing at the ground was over—some of the students had never been aloft—the three began to take notes. Note-taking, as well as use of topographic maps, proved easy for the better students. I made occasional suggestions, but most of the time confined myself to observing the elevation and the effects of

differing elevations on accuracy and range of vision. The following comments upon what could and could not be well observed are based chiefly on papers (one and a half pages, typewritten) required later from each student.

(1) Observation of faults: Physiographic evidences of faults seemed to be noted by all. Though the particular Whittier fault suggested for consideration was merely guessed at by all but two students, who connected a scarp behind the Brea oil field with the fault, another fault, the San Jacinto line, which bounds the Perris peneplain to the northeast of the Santa Ana Mountains, was observed by about two thirds of the students of their own initiative.

(2) The river terraces, due to uplift, were not well located; at least, statements concerning them were vague. On the other hand, a partially dissected and uplifted fan-terrace, never observed from the earth except as the students dutifully "knew" it was there, attracted their eyes as something plainly discernible and "new."

(3) The contacts were variously estimated as "clear" to "obscure." A color change between the red of the Lower? Cretaceous and the gray of the Upper Cretaceous was rather generally located. Frequently, also, mention was made of "being able to see the continuity of a contact across canyons and divides." Such observation strikes me as very valuable, even if the exact bed was wrongly allocated.

(4) The Perris peneplain was observed with enthusiasm and very early. "From 1,900 feet the hills on what we had been told on auto trips was the peneplain looked like bumps on a wide stretch of flatness."

Students seemingly were able to observe, though scatteringly, more than the required four points. Straightness of certain streams, youthful and mature topography, springs along fault lines, braided rivers, arrangements of oil wells, the shape of Santa Catalina Island far to the west, the asymmetricality of the Santa Ana Mountains from an elevation of 4,500 feet, silver mines in a dike ("I see now it *is* a dike," wrote one student)—these and other details drew comment in one or another paper. Average strike and dip of formations were often determined, though Brunton compasses were unusable.

On the whole, then, the experiment was a success, particularly in giving a bird's-eye instead of our ordinary ant's-eye view. The visibility was excellent; at 1,900 feet, our average elevation, gas station signs were entirely legible. The speed was about 100 to 115 miles per hour.

We plan, in connection with a field geology course for the same group of students next semester, to fly over a region unknown to them. If, as seems probable, this flight can be preceded by another over known territory, so that the students become more accustomed to note-taking in the air, the results of the third flight should be very interesting.

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SCIENTIFIC BOOKS

THE OPUS MAJUS OF ROGER BACON[1]

The Opus Majus of Roger Bacon: A Translation by ROBERT BELLE BURKE, Professor of Latin and Dean of the College, University of Pennsylvania. 2 volumes. Philadelphia: University of Pennsylvania Press, 1928.

AMONG the records of scientific thought we find here and there, separated usually by long intervals of time, certain books which stand out like landmarks. Broad and general in their scope, written by men who attracted unusual attention from their contemporaries, each book may be taken as a fair representation of the state of scientific thought at its best at the time the book was written. To the understanding reader such works present a picture of the intellectual life of their time as full and clear as Hogarth's drawings of the daily life of the eighteenth century London which he loved so well. Among such books may be mentioned Newton's "Principia" (1687), Gilbert's treatise "On the Magnet" (1600), and the writings of Roger Bacon (1266).

Taken jointly, these three books illustrate, for one thing, in graded succession a steady tendency away from the occult and the supernatural in scientific thought. The writings of Bacon are deeply tinged with the superstition of the Middle Ages, but by Gilbert's time, three centuries later, this element had become of minor importance, and in the "Principia," less than a hundred years after, it had practically disappeared.

It is easy for the twentieth century to be impatient with Roger Bacon; with his prolixity, his endless citation of ancient authority, and above all with his superstition. To our thinking, this latter seems inconsistent with a type of mind that delighted in the study of the anatomy of the eye, in optical principles and in their application to the rainbow. Indeed, the suggestion has not been lacking that he who upheld experiment and observed the stars from his tower at Oxford, who knew at least the pyrotechnic properties of gunpowder, must have been insincere in his monastic profession, desiring only the loaves and fishes

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

that the Church could offer him, in order that he might pursue those profane studies in which his real interest lay.

This opinion appears to have originated with his contemporaries. The common people suspected him of witchcraft (small wonder, with his fireworks!) and his superiors in the Franciscan order had doubts of his orthodoxy. That this latter opinion has survived to the present day is partly due to the fact that, buried in medieval Latin, the writings of Bacon have been unable to speak for themselves. In making it possible for us to become acquainted with the man himself, Professor Burke in translating the "Opus Majus" has done the scholarly world a service. May the reception of this work be such as to encourage him to do the same for the "Opus Minus" and the "Opus Tertium."

The reviewer comes from the reading of the "Opus Majus" with the feeling that Bacon was a misunderstood man even in his own day. It is impossible that one could maintain the part of a hypocrite to such perfection through the length of these two portly volumes. His words have everywhere the ring of sincerity. Bacon's recital of the story of the demon and the heretical bishop (Vol. II, page 816) is given with a childish faith that is touching.

When we turn from this to the famous passage foreshadowing the invention of the telescope (Vol. II, page 582) we may wonder at the apparent inconsistency of this grasp of natural principles with the superstition of the times, but in another passage (Vol. II, page 581) we see that to the medieval mind there was no inconsistency in the two. Bacon seems to have been acquainted with the phenomenon and cause of sun-dogs, for he says naïvely:

"Moreover, if one knew that the air is dense, so that reflection could be obtained from it, he might produce many unusual appearances of this kind. In this way we believe that demons show camps and armies and many wonders to men."

A sympathetic understanding of the "Opus Majus" requires a knowledge of the conditions under which it was written. For this purpose a parable may be helpful.

There was once a young man, ambitious and patriotic, desiring above all things to serve his country. As the most available means of self-expression in this respect he sought and obtained a minor clerkship in the Government service. In the course of time he became disillusioned. He found about him those who regarded their positions merely as means of making a living which, while neither luxurious nor ample, was at least safe and secure in troublous times. He was thrown into association with those who took no pride nor professional interest in their work, and who followed for the most part rules laid down by those long dead, which our hero saw clearly were no longer suitable to changed conditions.

Our young clerk followed a different course. He read and studied much, convinced that all knowledge, however remote it might seem from his daily tasks, could not but be beneficial and helpful to him and his fellows, and must contribute to the strength of that nation which they had all sworn to serve. He even went to the length of experimenting in the hope of finding new knowledge, a thing decidedly not done in the best official circles of his time.

More than this, he did not hesitate to speak his mind to those about him, superiors as well as equals, pointing out that new knowledge would be an excellent thing for them all professionally. But his superiors were old fogies. They refused to listen to him, and when his persistence became annoying they transferred him to a post in a distant city, sending with him injunctions to his new chiefs to keep him strictly to his duties and to put a seal on his lips.

And then—wondrous good fortune!—one of the few who had ever shown any interest or sympathy in him was elected president!

We may well believe that our hero lost no time in writing to him, and that with his congratulations he expressed the hope that this turn of affairs would be the means of lifting the civil service out of the rut in which it had so long moved.

His hope was not in vain. He soon received a kind and sympathetic letter from the president, asking (or rather commanding) him to write out fully his plans and ideas for the betterment of the service, disregarding any orders to the contrary that might issue from his immediate superiors.

Would he write? Will a duck swim? History records not the conclusion of the story, but without doubt our hero wrote as fully and completely and as hopefully as Roger Bacon, the Franciscan friar, wrote at the command of Pope Clement IV; wrote from his prison in the House of Franciscan Friars in Paris, whither he had been sent from Oxford as a troublesome character, under suspicion of witchcraft and heresy; wrote in defense of his studies and experiments, ever insisting that his motives were unimpeachable, and that such knowledge of the ways of Creation could not but redound to the greater glory of the Creator.

Bacon is commonly regarded as a lone instance of scientific activity in his day of tradition and scholasticism, a voice crying in the wilderness; but from the fact that at least one other intellectual took an interest in him, we may infer that there may have been others of his type to be found here and there, exceptional souls, "mute, inglorious Bacons," (with

apologies to Gray) perhaps equal to the Franciscan in all save opportunity. And for the opportunity and the protection afforded Friar Bacon the name of Pope Clement IV deserves to be held in grateful remembrance.

In Roger Bacon we see a man of natural ability fettered by the limitations of his time, a mind struggling toward freedom but handicapped by hereditary modes of thought. We should emphasize what he attempted to do rather than that which he failed in doing. Still upon every one of us tradition, convention, circumstance, lays a restraining hand.

> Thou little child . . . . .
> Full soon thy soul shall have her earthly freight,
> And custom lie upon thee with a weight
> Heavy as frost, and deep almost as life.

PAUL R. HEYL

AMERICAN ASSOCIATION OF PHYSICAL ANTHROPOLOGISTS

THE recent meeting of Section H of the American Association for the Advancement of Science (December 29–30, 1928) has resulted in an event of much importance to the future of physical anthropology in the United States and the neighboring countries. This event was the definite organization, on this occasion, of the American Association of Physical Anthropologists.

The need of such an organization has been felt increasingly for several years. An initial proposal for its realization was made in 1924 by Hrdlička, but to some of the workers the time then did not seem to be quite ripe. Since then developments in this country in physical anthropology, in its research, personnel, publications and its prospects, have steadily advanced, and it was felt more and more clearly that, as in the history of all other branches of science, the time had arrived when an organization of the workers in this line was becoming a necessity.

In view of these conditions Hrdlička presented the whole matter once more before the well-attended meeting of Section H, in New York, and it met with a favorable reception. As a result there met, following the session of December 28, about twenty anthropologists and anatomists, and each of these individually and unreservedly expressed himself in favor of the founding of a special association for physical anthropology. There was then elected a committee of organization with power to act, composed of Drs. Fay Cooper Cole, Charles H. Danforth, George A. Dorsey, William K. Gregory, Ernest A. Hooton, Aleš Hrdlička and Robert J. Terry; and this committee, assembled after the final session of Section H, December 29, adopted unanimously the following resolutions:

Resolved: I. That there should be, and hereby is, founded an organization of American and allied scientific men and women active or interested in physical anthropology, to be known as the American Association of Physical Anthropologists.

II. That the general object of this organization will be the promotion, by all legitimate means, of the interests and serviceability of physical anthropology.

Thereupon all present, as constituent members of the new association, proceeded to the election of the officers; the results were: *Chairman,* Dr. Aleš Hrdlička; *secretary-treasurer,* Professor Dudley J. Morton.

In the detailed organization it was decided to follow, in the essentials, the American Anthropological Association.

It was further decided that the new association shall cooperate, to the limit of possibilities, with the American Anthropological Association, with Section H of the American Association for the Advancement of Science and with the American Association of Anatomists.

A still further basic principle of the new organization will be the fullest possible support of the *American Journal of Physical Anthropology,* which will be its official medium.

The eight initial members were then charged with the preparation of a detailed platform of the new association, the understanding being that its activities will be directed, in main, to the following objects:

(1) To the promotion of contacts, of cooperation and of service in this and other countries, with all branches of anthropology; with the anatomists and physiologists; with the biologists, and with medicine and dentistry.

(2) To the promotion, in the broadest sense, of research and publication in physical anthropology.

(3) To the promotion of sound anthropological teaching in universities, colleges, medical schools, art institutes and all other establishments of learning where such instruction, in suitable forms, would be useful.

(4) To the preparation of proper text-books, charts and other aids to anthropological instruction.

(5) To the promotion and harmonization of anthropometric instruction, and to that of standardization and production of anthropometric instruments in this country.

(6) To the extension of standard methods of measuring, with proper metric instruments, into all

colleges and other establishments where measurements of many subjects are being taken, such as institutions for children, institutions for special classes of defectives and abnormals, insurance companies and the recruiting stations of the army and navy.

(7) To the furtherance of the same methods, instruments, etc., in other countries.

(8) To the development of physical anthropology as a well-organized branch of science in order to insure its greatest practical value and educational benefits for future generations.

(9) To the popular dissemination of the results of scientific research in physical anthropology.

(10) To the furthering and assisting, in our museums, universities and colleges, of the best possible exhibits in human phylogeny, ontogeny, variation and differentiation.

(11) To the aid of advanced and worthy students to original research and field work. And,

(12) To the eventual establishment, in the most favorable location, of the "American Institute of Physical Anthropology," which would serve both as the home and library of the association, and as the center of anthropometric instruction and of dissemination of anthropological knowledge.

The association will consist of active and associate members.

The condition of active membership will be sound original work in or closely related to physical anthropology. Associate members will be all such persons from collateral sciences, or at large, who may, through sympathy with the objects of the association or a desire to benefit from its activities, wish to join its ranks; they will have the privilege to participate in the meetings of the association, without voting.

The annual membership dues, for both active and associate members, are fixed at $2.00 per year. There will also be patrons and life memberships. Applications for membership should be addressed to Professor D. J. Morton, secretary-treasurer, Department of Anatomy, College of Physicians and Surgeons, Columbia University, 630 W. 168th St., New York City.

ALEŠ HRDLIČKA
Chairman p. t. A. A. P. A.
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SPECIAL ARTICLES

CIRCUIT TRANSMISSION AND INTERFERENCE OF ACTIVATION WAVES IN LIVING TISSUES AND IN PASSIVE IRON

THE material in which the primary chemical reactions of stimulation take place in living irritable tissues, such as nerve and muscle, is evidently not in homogeneous solution; the indications are that it is situated (*e.g.*, adsorbed) at the protoplasmic phase-boundaries, *i.e.*, forms part of the thin, electrically polarizable surface-layers of the protoplasmic structures concerned. This is implied by such general facts as the universal responsiveness of these reactions to the electric current and their sensitivity to the presence of surface-active compounds (narcotics). According to the chief prevailing conception (membrane theory) of the primary stimulation process, the material in question is a component of a thin, continuous interfacial film or membrane which undergoes both chemical and structural change during stimulation. Two constant features in the response of an irritable tissue to stimulation are (1) that the reaction never remains localized but tends automatically to spread, often rapidly and to an indefinite distance, as in nerve, and (2) that the tissue is always inert and irresponsive for a brief period after excitation (refractory period). The recovery which occurs during this period is an index of the restoration of the reactive surface-layer to its original structure and composition. It is as if one had a thin sheet of explosive material which is completely broken down in each reaction ("all-or-none" behavior) and is then immediately renewed. Evidently in a system so constituted the reaction occurring at any point is temporary, and maintained activity is necessarily intermittent or rhythmical. In the muscle or nerve the state of chemical and other activity resulting from a single localized stimulation travels along the irritable element in the form of a wave. When the excitation process at any point is rapid, as in nerve, only a limited area is occupied at any instant by the reaction; this active stretch constitutes the excitation wave (contraction wave, nerve impulse); in a vertebrate motor nerve it is at most only a few centimeters in length.

If the anatomical relations are such that the excitation wave can return to its starting-point, as by passing around a continuous circular path, it may continue its motion indefinitely, provided the tissue has recovered sufficiently in the interval between successive circuits. Such circuit transmission is not normally found in the intact animal, but it can readily be obtained experimentally in certain instances. Hitherto it has been studied chiefly in circular strips of neuromuscular tissue cut from the hearts of the larger cold-blooded vertebrates and the subumbrellar tissue of medusæ. A contraction wave started in one direction in such a strip will often continue its circular motion for hours or even days. These tissues are alike in having relatively slow rates of transmis-

sion and well-marked refractory periods. I have also observed striking instances of the phenomenon in strips of ctenophore tissue containing a row of swimming plates; such strips (*e.g.*, 3 to 5 cm long) often round off in sea-water in such a way as to bring the opposite ends of the row close together; waves of ciliary movement then cross the gap and travel uninterruptedly around the ring, often for hours at a time.[1] In rings cut from the heart of the loggerhead turtle Garrey obtained circus contractions lasting continuously for hours, and Mines made similar observations on the hearts of sharks and rays.[2] In the medusa Cassiopea Mayor and Harvey obtained "trapped" contraction waves which continued steadily for days at rates of 15 to 60 cm per second, traveling distances estimated at many miles.[3] Such experiments are of interest as illustrating the perfect regularity and automaticity of the processes underlying stimulation, transmission and recovery in these tissues. It should be noted that trapped excitation waves of this kind may become a source of deranged coordination in organs whose normal activity depends on regular transmission in one direction; thus both Garrey and Mines have pointed out the intimate relations of this phenomenon to cardiac fibrillation; and the possibility should be considered that similar types of derangement may occur in the central nervous system.

Two chief conditions for circuit transmission are as follows: (1) The excitation wave must be of limited length, so that at any instant it occupies only a restricted portion of the circuit; and (2) its rate of movement must be relatively slow, so that the time required for the wave front to travel the distance of the circuit (less the length of the wave itself) is greater than that occupied by the recovery process (refractory period) of the tissue. Under these conditions the activation wave is continually entering a region of tissue which is sufficiently recovered to permit of further transmission. Hence its progress continues automatically until it is arrested by some secondary change of condition, such as interference, exhaustion or injury. The length and speed of the excitation waves are usually such that the ring must be of considerable size, *e.g.*, some inches in diameter, if the circular transmission is to continue indefinitely; this, according to Garrey, is the reason why only the larger hearts readily undergo fibrillation. According to his conception, reached independently also by Mines, fibrillation is a result of the formation of local closed circuits in which contraction waves may circulate without interference. Evidently the length of any such circuit must be greater than that of the excitation wave if the conditions for the periodic renewal of the wave on its completion of the circuit are to be met (see Mines's diagram, *loc. cit.*, p. 374). Analogous conditions are found in passive iron wires; irregular waves of activity resembling fibrillation are readily obtained in longer lengths of Armco wire in HNO_3 of 78–80 v. per cent. concentration[4] but not in shorter lengths.

Attempts to obtain circuit transmission of a similar kind in rings of passive iron wire in nitric acid have hitherto met with only partial success, chiefly because the two necessary conditions, short length of simultaneously active region (activation wave) and rapid recovery of transmissivity, were never found combined in a single wire. Either the non-transmissive period immediately following activation was too long (as in the steel wires used in my earlier experiments),[5] or the duration of the local activity was too great in relation to the speed of transmission, so that the whole wire became simultaneously active. I have tried increasing the concentration of acid; this change of condition shortens the duration of the local reaction, thus decreasing the length of the wave, without greatly affecting the rate of transmission; but unfortunately this procedure also rapidly lengthens the period of recovery, so that the return of the wave finds the wire still non-transmissive. In steel wires the non-transmissive period is so long—some minutes in 70 v. per cent. HNO_3 at 20°—as to make any practicable arrangement quite impossible.[6]

Recently, however, I have found that pure iron wire of low carbon content (electrolytic iron or Armco iron) has a very brief recovery period,[7] measured in fractions of a second in 70 to 80 v. per cent. HNO_3 at 20°; it thus becomes possible, without unduly prolonging the refractory period, to use acid so strong that the active stretch of wire during transmission is only a few centimeters in length. When the temperature, concentration of acid, and interval since previous activation are properly adjusted, activation waves 10 to 20 cm long are obtained which travel at moderate speeds, of 10 to 30 cm per second. In rings of wire not more than 20 cm in diameter the recovery time is less than the time taken by the wave to complete the circuit, so that under appropriate

[1] Observations on Eucharis and Beroe in the Naples Zoological Station in 1904–5 (*cf.* Carnegie Year-book for that year).

[2] Garrey, *Amer. Jour. Physiol.*, 1914, 33: 397; Mines, *J. of Physiol.*, 1913, 46: 349.

[3] Mayor, Carnegie Inst. Bull. Publ., 1908, 102: 113; Harvey, *ibid.*, 1910, 132: 29, and Carnegie Year-book, 1911, 10: 130.

[4] Volumes of HNO_3 (C. P. sp. gr. 1.42) in 100 volumes of solution.

[5] *J. Gen. Physiol.*, 1920, 3: 107, 129; and 1925, 7: 473.

[6] *J. Gen. Physiol., loc. cit.*

[7] SCIENCE, 1928, 67: 593.

conditions typical continued circuit transmission is readily obtained.

The wire used in the present experiments was the pure low carbon wire known as Armco,[8] 2 mm in diameter. In order to secure the conditions for a regular progressive movement of a trapped activation wave it is necessary to have the ring of wire surrounded by a continuous column of acid of uniform and not too great width—*i.e.*, by a ring or sheath of acid—instead of lying free in a large continuous volume, as in an open dish. In the latter case it is impossible to keep the activation wave sharply defined and limited in length, because of distance action between the active area and the passive area on the opposite side of the dish. Contact of the wire with the walls or bottom of the vessel must also be avoided, because of irregular local activity set up at such regions.[9] These conditions have been satisfactorily met by the following arrangement. The wire ring is freely suspended by thin glass hooks in a circular trough, *ca.* 2 cm in diameter, containing the acid. This trough is made by cementing a section of glass cylinder, *ca.* 5 cm high and 20 cm outside diameter (cut from a large bottle), to the bottom of a crystallization dish of 24 cm inside diameter and 6 cm depth. The bottom of the trough is covered by a layer of paraffin (to protect the cement against the action of the acid). A satisfactory apparatus has also been made by partly filling a crystallization dish with paraffin and cutting out a trough around the margin. The wire ring (*ca.* 22 cm in diameter) is suspended at *ca.* 1.5 cm from the bottom in a layer of acid 3 cm deep. The temperature is regulated by a water-bath. The wire ring is *ca.* 70 cm in circumference. It is made most conveniently by cutting the required length of wire, bending it into a circle and hooking the two ends together. Usually it is necessary to insert a small piece of platinum wire at the junction where the two surfaces of iron are in contact; otherwise a persistent action is likely to be set up at this region, from which rhythmical waves of activity spread over the wire in both directions, making regular circuit transmission impossible. In some experiments the two ends of the wire have been welded to make a continuous ring. In certain respects this procedure is preferable, but the welded region often acts at first as a block to transmission, apparently because of the formation of iron oxides. If, however, such a ring be kept in strong HNO_3 for some time the block disappears and the activation wave then passes the junction smoothly.

The concentration of HNO_3 suitable for circuit transmission under these conditions is 75–80 v. per cent. In weaker acid the active stretch of wire (*i.e.*, the activation wave) is too long; in stronger acid the wave is shorter but the return of transmissivity is too gradual. In acid of 78–79 v. per cent. at 15° the activation wave is typically 12–15 cm in length and its speed is about 15 cm per second. Any single region of the metallic surface thus passes through a cycle of chemical change lasting about one second, consisting in a reduction and dissolution of the passivating surface film followed by its reformation under the oxidizing influence of the acid and local electric circuit. By the time the wave has completed the circuit the wire is sufficiently recovered and transmission continues uninterruptedly.

Interference of Activation Waves

When the passive wire, arranged as above, is touched with zinc at any point two activation waves are started which travel in both directions from the contact; these meet on the opposite side of the ring and there immediately extinguish one another, the whole wire becoming again passive. This experiment may be repeated as often as desired at intervals of two or three seconds with always the same result. A similar interference of excitation waves in living tissue has long been known, and is shown clearly in rings cut from large hearts or medusæ. Two equal contraction waves traveling in opposite directions and intersecting undergo mutual extinction.[10] In the passive wire interference is also readily demonstrated in a long straight wire immersed in acid and touched simultaneously at opposite ends, or in a vertically suspended wire over which a thin stream of acid is kept flowing from a siphon; in the latter case the movement of the waves is slow (2 to 4 cm per sec.) and the details of the phenomenon can be observed more closely. The effect itself is a direct consequence of the intersection or superposition of the two oppositely oriented local electric circuits of the two waves; the associated electric currents annul one another by compensation and the dependent chemical action ceases. Electrochemical interference of this type is a possibility in the case of any reaction occurring at an interface under the influence of a local circuit. The fact that it is equally characteristic of activation waves in living tissues constitutes further evidence that the primary chemical reactions of excitation and transmission in protoplasm are surface reactions controlled by local bioelectric circuits.

[8] American Rolling Mill Co. The carbon content is given as less than 0.1 per cent. This wire was also used in my experiments on rhythmical action: *Archivio di Scienze biologiche*, 1928, 12: 102, and SCIENCE, 1928, *loc. cit.*

[9] R. S. Lillie, *loc. cit.*, 1928.

[10] *Cf.* Mines and Mayor, *loc. cit.*

CIRCUIT TRANSMISSION

When the passive wire is held at one region with a pair of platinum-tipped forceps and is then touched at a neighboring point with zinc, the activation wave thus started is blocked at the platinum, while its progress in the other direction is unhindered. If the platinum be withdrawn before the circuit is completed an isolated activation wave is left in the wire; this continues its movement in a manner analogous to the trapped excitation waves in living tissues. The spectacle is a striking one; the dark, slightly effervescent area corresponding to the active stretch retains a nearly constant length (*e.g.*, 15 cm), and moves with remarkable uniformity round and round the wire in one direction. Unless some accidental condition interferes, or the materials are depleted, the movement continues indefinitely. At any time the progress of the wave can be stopped by contact with platinum; the whole wire then becomes passive.

The following are typical speeds of transmission observed in a single wire in the same bath of acid (79 v. per cent.) at different temperatures:

Temperature	Speed (cm per sec.)
8°	8
13–14°	13–14
18°	24–25
23°	33–35

It is noteworthy that the Q_{10} values (2.5–3) are higher than those usual with nervous transmission or transmission in fully recovered passive iron. This is because the rate of travel of the wave in circular wires is limited by the degree of recovery which the wire has reached in the interval between successive circuits. The temperature coefficient of recovery, both in living tissues and in passive iron,[11] is typically high (Q_{10} = 2.5–3.0). The speed of the activation wave in passive iron is slowest immediately after the return of transmissivity and gains its final value by a progressive increase, following a curve resembling a parabola.[11] A similar behavior is seen in heart muscle (Mines)[12] and in nerve (Forbes).[13] The return of the definitive or final rate of transmission at any temperature is thus determined by the rate of recovery. What is illustrated by the foregoing observations is in reality the temperature coefficient of recovery; the coefficient of transmission in wires that have reached a stationary condition is much lower (Q_{10} = 1.4–1.5 in steel wires between 5° and 20°).[11] A relatively low temperature coefficient is also characteristic of transmission (as distinguished from recovery) in nerve and muscle.

With regard to the chemical aspects of the phenomenon certain general features may here be briefly considered. As is well known, transmission in passive iron depends on the cathodal reduction and consequent breakdown of the thin, passivating surface-film of oxidation-product at the region adjoining the already active area. The repassivation which follows automatically in stronger acid is an effect of the reformation of the film by the oxidation of the exposed metal. Any area of metal is thus only momentarily active in strong acid; and since active areas are anodal, the electrochemical oxidation there occurring must be recognized as an essential factor in the repassivation process. This process restores the wire to its original state, and in this sense is comparable with the recovery process in living tissues. As the activation wave travels over the surface of the wire there is an alternation of reduction and oxidation at each point reached. The reduction corresponds to the activation, which is automatically transmitted in the manner indicated. The oxidation plays no direct part in the transmission, but is immediately responsible for the return to the passive or resting state, *i.e.*, for the recovery part of the local cycle of processes. In the general nature of the chemical processes constituting the reaction cycle there is here seen a broad correspondence with the conditions in living tissues such as nerve and muscle; in the latter case also the primary process of excitation appears to be independent of oxidations; these, however, are essential to recovery, as is indicated by the importance of free oxygen to this process. It would thus appear that in both the living and the non-living systems the renewal of the chemically reactive surface layer in which the essential process of activation occurs depends on the formation of some oxidation product or products. In the case of passive iron we know experimentally that when this product is rapidly reduced there follows a structural change, disruption of the film, giving rise directly to the local electrical change which forms the primary condition of activation and transmission. Conversely, oxidation restores the film, rendering transmission again possible. The structural, chemical and electromotor changes in the surface layer are interdependent; the law of polar activation, applicable to both systems, thus becomes intelligible. The specific nature of the chemical processes associated with excitation and transmission in living tissues, such as nerve, can be determined only by special investigations on the metabolism of these tissues during rest and activity.

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[11] R. S. Lillie, *J. Gen. Physiol.*, 1925, 7: 473.

[12] Mines, *loc. cit.*

[13] Forbes, Ray and Griffith, *Amer. J. Physiol.*, 1923, 66: 553.